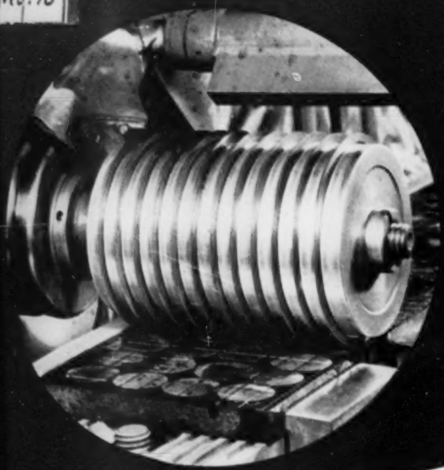
R/E RESEARCH & ENGINEERING

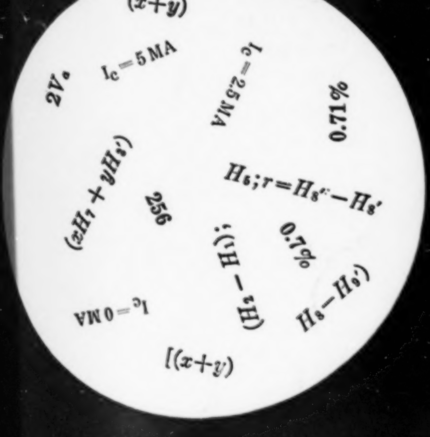
FOR RESEARCH & DEVELOPMENT MANAGERS

OCTOBER 1956



WEANING THE ENFANT TERRIBLE

CREATIVITY IN R/D TEAMS



RESEARCH CONTROL

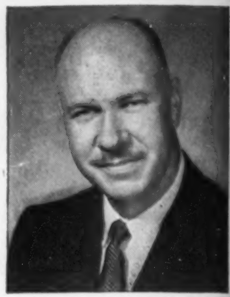
Westinghouse's Investment in Tomorrow

Triumph of the Material Designers: 500°C Circuits

High-Pressure, High-Temperature Chemical Reactors

TECHNICAL MANAGEMENT

Merritt A. Williamson



HARNESSING THE HUMAN DYNAMO

Recently I received a letter of particular interest, which points up what I consider to be one of the most serious difficulties encountered in our present day research and development operations. The writer was seeking my advice, but I am sure it would be helpful to receive suggestions from interested readers, or from people who find themselves in a similar plight. Any ideas are welcome. This is a management clinic!

The problem in its simplest terms is what to do with the above-average man—the gifted individual who cannot find it in himself to conform. When we hire research and development personnel or creative people in any line we expect them to be productive of new and different ideas resulting in profitable innovations. If we expect unconventional thinking in the area of science and technology, shouldn't we expect non-conformity in other areas as well? Must we not expect to have a "problem child", and don't we welcome him if he is truly creative?

This non-conformity may show itself in many ways. We have the person who will not abide by regular working hours. He works, or claims to work on "inspiration", and he claims that he cannot get inspired if he must come to work at a regular hour every day. He claims he can think much better on certain occasions by remaining at home. He maintains that he spends much more time on his work when he can do it in the peace and quiet of his study (enhanced, perhaps, by a little liquid refreshment from the nearby refrigerator)!

In some cases there is no resentment of the working hours, or at least no complaint, but there is loud and vociferous protest against routine details like having to fill out time cards, write weekly progress reports, attend committee meetings, etc. Or we may run into the person who does not like his assigned space. His desk is too far from the laboratory, it faces in the wrong direction, or he doesn't want to share his office with any other person. Non-conformists come in all sizes, styles and types; they make life interesting for the administrator. Of course we all know the ready critic who could run the company far better than its officers.

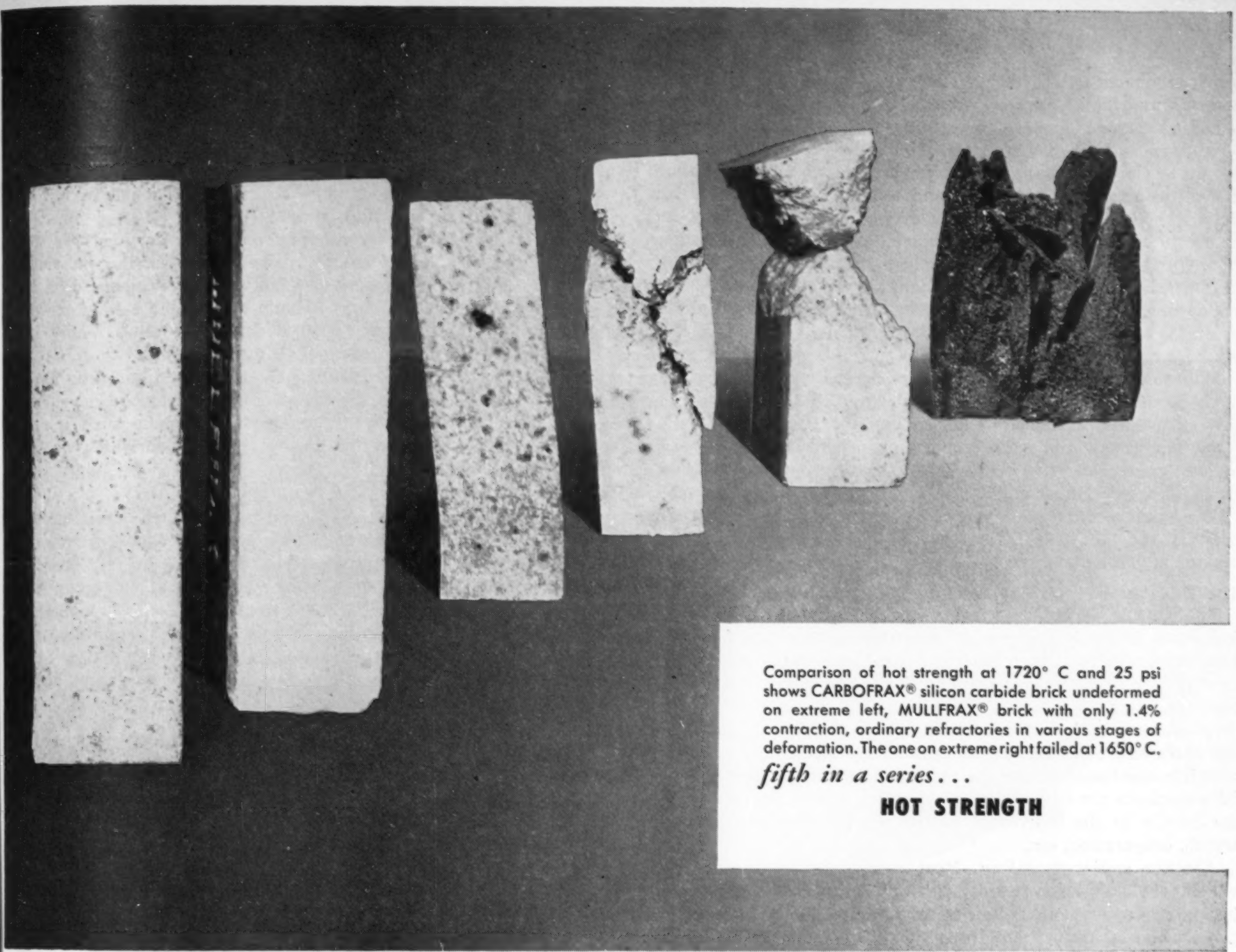
The Stakhanovite

This month, however, I wish to direct attention to another type of non-conformist; the man who is driven to produce at a rate far in excess of those around him. These men, who operate at a high rpm are a disrupting influence, and they can sometimes cause serious morale problems in an organization.

All of us, I am sure, have given thought to the fact that we seem to be catering to the average. Some even say that we are being gradually ground down to mediocrity. In school, our instruction is geared to the average child. True, we do have schools for the below average and the retarded, but we have very few schools for the specially gifted. This is serious when we reflect that our future may rest on these gifted youngsters. We have seen the great levelling tendency being exerted in the area of salaries and wages. The pay and prestige differential between skilled and unskilled labor is gradually diminishing. It has even been demonstrated by mathematics that the investment in education to obtain higher degrees is not an economically sound one.

We often see remuneration scales set by years of work on a job rather than by personal considerations such as speed, accuracy, productivity, etc. A man may work for 20 years with each year being different, and thus become a valuable experienced worker, or his 20 years may be made up of one year's experience repeated 20 times. It is not my intention to decry this system or discuss its philosophic implications for the future. It is a condition which is with us whether we approve of it or not, and we know that it is affecting our organizations.

Out of this environment comes one of technical management's greatest problems. It is true that we can advance some people in an organization at a more rapid rate than others, but we must be constantly prepared to defend our reasons or we may produce poor morale. To depart from routine average raises requires very careful study and observation by the manager. He must be close to his men and discerning in his evaluations. The manager has many other things to do, and if he is more project-oriented than personnel-minded, this problem is a never ending source of discomfort. In addition to the time which must be spent in careful study of individuals, there is the increasing demand on time to explain the rationale of salary. If it is not explained from time to time, morale is bound to suffer. Moan or wail as we will about



Comparison of hot strength at 1720° C and 25 psi shows CARBOFRAX® silicon carbide brick undeformed on extreme left, MULLFRAX® brick with only 1.4% contraction, ordinary refractories in various stages of deformation. The one on extreme right failed at 1650° C.

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FOR MORE INFORMATION CIRCLE 2 ON PAGE 48.

poor communication, there is no lack of it where salary increases, bonuses, and the like are concerned.

Let us consider some of the things which frustrate the man of high rpm. He is driven by the job and he expects others to be driven in the same way. He regards anyone who does not share his enthusiasm for long hours and tedious tasks as a slacker. Some people will not work for a driver. Others will work but refuse to be driven beyond their normal pace; hence the frustration. Our system of overtime pay adds to the problem. In many organizations all persons, professional and non-professional, who are not members of supervision receive overtime pay for all hours in excess of 40 per week. In some organizations there is a limit placed on the number of hours that may be worked per week. Furthermore, if employees are to work overtime, their names must be submitted in advance and approved. All this extra work and extra overtime adds to the expense of R/D. In fact it is sometimes considered more economical to hire additional people including nonproductive workers in order to keep the costs down. In the larger organization which results one can ask how many of the engineers, whose work is so carefully subdivided, really feel that they are growing and learning at a rate that gives them maximum job satisfaction.

The Individual Is Out of Fashion

The pressure to conform is tremendous in today's society. The *individual* is not in fashion if he has too hard a time fitting in. How many potentially high speed producers have deliberately slowed themselves down so as not to irritate or annoy their fellow workers, their supervisors, or their subordinates? How many of them, observing the differential in take home pay accompanying the extra effort of carrying along a slower team, have concluded that life was too short for the struggle? How many technological advancements are missed through creation of environments which are hostile to the individual who excels by emphasizing "team work", cooperation, etc.

Another aspect is safety. Most companies have regulations which forbid a person to work in the laboratory after hours unless he has a companion. This is for his own safety as well as to protect the laboratory building. Suppose a man gets a genuine inspiration at midnight when he is at home. Will he call up the director and ask permission to go to the laboratory? Will he call a friend to sit up the rest of the night and work with him? Will he write down his ideas? Probably not. If he did he might lose the intensity of thought. He may need to perform actual laboratory manipulations in order to fix it in his mind. Then too, the approved notebooks for disclosures are not to be taken from the laboratory under any condition, and regulations call for all entries to be made in the approved notebooks! Some laboratories even make the notebooks of such size that they cannot be taken with the worker, but must be left on his desk which has to be cleared every time an entry is to be made! With the tremendous difficulties that are encountered, is it any wonder that it is easier to go to bed and forget about the whole thing?

Getting Into Phase

Psychologists have long recognized that each person leads a cyclic existence. We are not all productive at the same hours of the day. Some people do their best work in the morning, others in the afternoon and still others reach their peak after ten o'clock at night. Yet industry for the most part decrees that the work day shall begin at eight and end at five. In many laboratories one has to search to find anyone at work after closing time.

Of course, the closer to basic, fundamental, non-applied research a man may be working, the less disrupting his erratic schedule may be to others. Even here, however, he often needs the services of the shop. I am sure we all can recall seeing technicians get in on time, and then wait around until their supervisor arrives because they do not know what may have happened after they left the day before. In development, design, and prototype production there is certainly less opportunity for a man to work at his own pace.

Opinions as to whether or not you think I have portrayed this problem in an exaggerated fashion will be welcome. What do you do about the rest of the staff when a man is capable of working and wants to work at high speed? How do you keep him from irritating others, or keep others from irritating him? To what extent are you, as a manager, justified in allowing individuals to choose their work hours? What other problems does this worker cause? Would you knowingly hire such a person or would you prefer to ride along with a smooth running team? Is a smooth running team necessarily a mediocre one?

I am reproducing my correspondent's letter in slightly altered form. I am sure you will see the similarity to persons in your own experience. How does your organization handle such a man? What would you advise him or the organization which wants to hire him?

The Letter

"I am writing to see if you could help with a personal problem of mine. I am in my forties and am a graduate B.S. from one of our better known institutes of technology. I have had nearly 20 years of experience in industrial and management engineering with some general, civil, electrical and mechanical engineering thrown in. I am presently receiving $9000 per year although I have earned more in the past and hold the rank of a Senior Engineer in the Research and Development Department and report directly to the Director. I have been with a management consulting firm until recently. I am characterized as a "human dynamo" due in part to satisfying my former clients in getting things done as soon as possible and have never lost a day's work because of illness. In fact I welcome long hours of work—even Saturdays and Sundays.

"Specifically I am too fast with deliverance of new ideas in R & D of new products for the multi-channeled organization to investigate. I wish to head up instead a combination Industrial Engineering and Research New Products Development department of my own with men of my own choosing, perhaps not more than three or four engineers and toolmakers for any type company where there is a challenge. Along with these three or four men and a small laboratory I wish to carry out immediately and to final stages all ideas that are evolved by me and my associates. These must be willing to work long hours day and night until final favorable results are forthcoming. After which period comes a rest until correlation with final market survey results and then on to lucrative development. Methods used would be trial and error coupled with empirical efforts—a two pronged attack with no red tape or preliminary scientific reports. I simply want to get things done—trying one thing after another as rapidly as possible day and night until completion.

"Perhaps my greatest asset is dynamically sparking a project from beginning to end. . . . But the possibility of friction comes in at the point where one is told he must 'get along with everyone'. One simply cannot be a 'human dynamo' and still 'get along with everyone'; 'getting along' will mean a high cost of overhead with more and slower by far man-hours of research and development if any results at all emerge."

Here we have it. Is this man an asset or a detriment to a research and development organization? What sort of operation should he work in? Is he a disappearing breed? Can he be utilized as he is or must he conform? Would you hire him? If so, how would you fit him into an organization to make the most effective use of him? Let's have some discussion on this.

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EDITORIAL

INTERNATIONAL RESEARCH | A new frontier

Here's an idea worth more than just cursory thought on the part of those engaged in either the conduct of research and engineering or its financing. Let's start with three pretty safe assumptions:

- Applied research in this country is proceeding at such a pace that men in charge of developing new products and processes are severely concerned with the rate at which we are using up our stockpile of basic research data. Providing a steady source of inflow into this stockpile to meet the needs of applied research and development is now a serious problem; more and more time of R/D teams is being spent in investigations of a fundamental type before applied work can proceed.

- In relation to the industrial demand and need existing in our country, we face a severe shortage of *qualified* research and engineering talent, particularly for work of a basic nature that is so important to our applied R/D efforts. For the past 15 years we slowly depleted our universities of some of their best men—men who normally would have been instrumental in training research scientists and engineers at the PhD level. Belatedly, we have begun to rectify this situation but best estimates are that it will take at least ten to 15 years before our universities are back to par.

- In Europe, particularly in countries such as Italy and Austria, there is a surplus of good scientific, engineering and research talent in comparison to available industrial support and opportunity.

Now let's look at one possible and feasible solution that could have far reaching effects for all of us, personally and corporate-wise.

This problem on both sides of the Atlantic could be met by an organization that would channel some of the problems of American industry into the individual laboratories of European countries that now do not have adequate industrial support. This organization could be a corporation operating in a public service fashion whether the corporation is profit making or not. A small staff of people in this country could correlate the problems of American industry with available talent in European laboratories. In Europe, small staffs could be set up to find European talent and arrange appropriate contractual arrangements for the study of specific problems as well as exercise a certain degree of supervision on behalf of American sponsors. These men would also report back to American sponsors on the progress of the work. A side activity of the European staff would be to promote, educate and further the entire cause of applied research by helping European companies to find answers to their problems—technical, economic, or managerial.

This proposed solution to a generally admitted problem is advocated by Jesse E. Hobson, formerly Director of Armour Research Foundation and for the past eight years Director of Stanford Research Institute. Hobson, recently returned from a European trip, had this to say particularly about Italy. "Italy has excellent research talent, but much of that talent is not now given adequate financial support. University professors' salaries are low, equipment and facilities are limited with only limited funds available for graduate students. However, the creative and imaginative abilities of the minds of Italian scientists and engineers are Italy's greatest resources. Certainly the talent should be left in Italy where it has been nurtured and where it can work best; past experience has proved that such talent is often not as creative and productive when taken out of its native environment. Much of the future strength of Italy, industrial and economic, could well reside in the development of creative talent for both basic and applied research."

Import-Export Research

The need for scientific and engineering assistance by industry in the United States, the availability of such talent in Italy and the need to develop further the scientific and research structure of Italy, led Hobson to suggest that some plan be developed for the mutual benefit of Italy and the United States.

For example, Hobson suggests that the creation of such a corporation be established jointly by Americans and Italians. This organization would have a staff of perhaps

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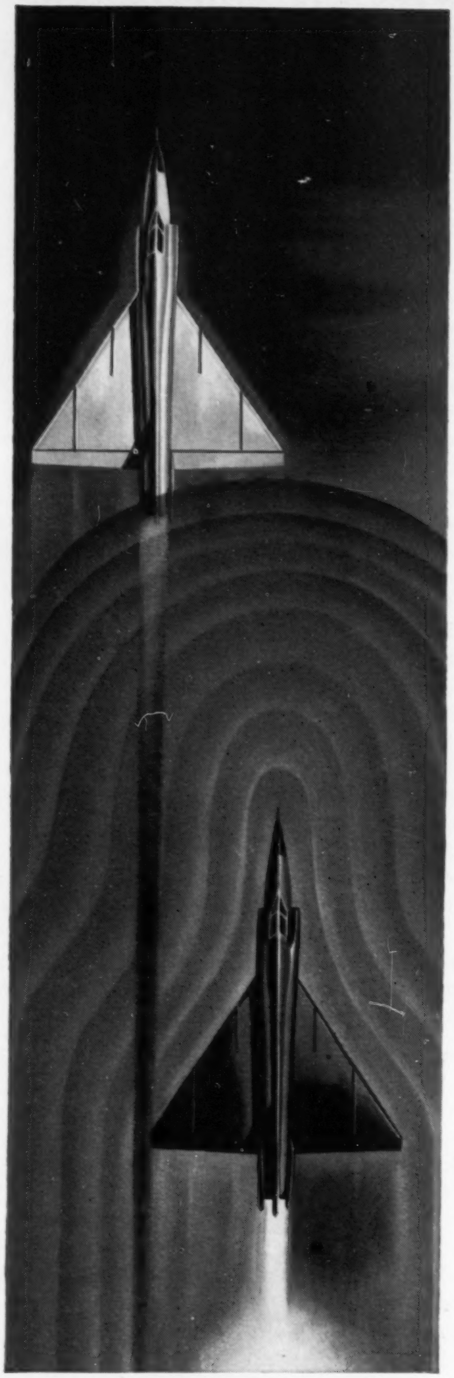

BACK when airframe construction first switched from wood and fabric to light metals — the thin alloy skins were actually sewn together with piano wire. Manufacturing methods had not kept pace with materials development.

Today, with supersonic aircraft nudging the thermal barrier, there's another big switch underway . . . a change to heat-resistant, high-strength alloys (steel, titanium, stainless).

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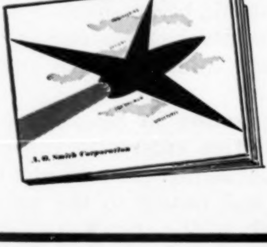

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FOR MORE INFORMATION CIRCLE 4 ON PAGE 48

five or six Americans and two or three Italians in the United States to contact American industry, find the problems which could be assigned to Italian laboratories, bring information to American industry regarding available talent and technical developments in Italy and arrange contract details with American companies.

A similar staff in Italy could find available research talent in Italy, maintain contacts with Italian technical developments, exchange scientific information and arrange specific contracts with Italian research individuals or organizations in the universities and industrial laboratories.

A central organization could maintain contact with work in progress, provide for supervision and assistance particularly in the preparation and distribution of reports and in the interpretation of the end results. An effective program of public information and public relations could be maintained to stimulate Italian researchers in universities and in industry, and to inform Italian industry of applied research and development opportunities.

Hobson suggests that the board of directors and the control of such an organization consist of representatives of Italian and American industries that furnish funds to create the organization and maintain its operation during the initial period. He also suggests an advisory board of Italian scientists and engineers from universities, industry and government; with a similar advisory board from American industry and research organizations.

Here's an outline that Hobson feels could get an organization like this rolling. Because Austria is in a situation quite similar and parallel to Italy's, both countries are included in his suggestion. With fewer industrial opportunities in Austria, and with even lower salaries for research engineers and university scientists, some of the best research talent is being forced to find employment opportunities in other countries. The Austrians are well aware that the future welfare of their country is being seriously threatened by this exodus of talent—the future of their economy, their industry and their universities.

The Plan

Four to six months would be required to study the feasibility of the overall plan including details of organization, policy, legal problems, tax matters and corporate structure. This cost could be shared by the United States (dollars from American industry) and by participating European countries (e.g., lire from Italian industry and schillings from Austrian industry).

An additional few months would be needed to arrange adequate financing for the corporation, again half from private sources in the United States and half from private sources in Europe, payable in local currencies (contributions, if a non-profit or sale of stock if a profit-corporation).

Obviously the organization could not be self-supporting from its beginning but Hobson believes it could be entirely self-supporting after a period of three or four years. It should be self-supporting after reaching a contract volume of perhaps $2,000,000 per year. Hobson feels the organization should operate with a surplus of 15 percent or more of its contract volume after reaching the break-even point. Subject to authorization of the board of directors, one-third of the surplus might be allocated to the expansion of the organization and extension of its services; one-third be allocated in grants for the support of basic research and for public service research in the participating European countries; and one-third be allocated in grants to universities for the support of basic research in the United States. The financial success of the corporation would thus be a direct benefit to all countries in supporting university and basic research; and the contract work performed through the corporation would be of immediate and direct benefit to both industry and the universities.

To establish itself properly and to show its long range objectives, the corporation should support basic research in Europe and also support public service research from the very beginning, he suggests, even before it came to the break-even point. For the inclusion of this type of activity including an extensive program of public information while bringing the operation to a self-sustaining basis, Hobson estimates a total fund of $2,000,000 might be necessary. He emphasized that no "quid-pro-quo" benefit would be promised or provided to the financial contributors (if a non-profit corporation were established) except the creation of the organization, its development to a self-supporting operation and the long-range benefits it could and would bring to countries on both sides of the Atlantic.

The Results

Applied research would be extended and furthered in these countries, basic research would be encouraged and strengthened and American industry would have sorely needed technical assistance. European industry would most certainly benefit over the years since additional technical know-how could be developed "in situ". The program would certainly assist the development of qualified and technical brains in all participating countries for basic and applied research and engineering. Since the activity would be entirely private enterprise with no government funds or government control, its profits or surplus could support basic research in outright gifts and grants to European universities and American universities on a 50-50 basis. Thus, the more successful the operation became, the more money would be available for the general support of basic research on both sides of the Atlantic. The same general approach and policy could be followed for a profit corporation after meeting minimum requirements of initial stockholders.

Hobson has discussed this idea with a number of industrial leaders in this country and abroad. There appears to be enthusiasm for an approach of this sort, and it has the significance worthy of the attention of as wide and as large an audience as possible while it is still in a tentative stage.

Although Dr. Hobson has spent considerable time and effort discussing this idea with individuals in this country and abroad, as he did publicly at the Tenth Annual Conference on Administration of Research last month at Pennsylvania State University, he has not identified himself with any specific plan for international research. His main thesis is that there should be an effective channel of international research and development cooperation within the framework of private enterprise, and that it should be established now.

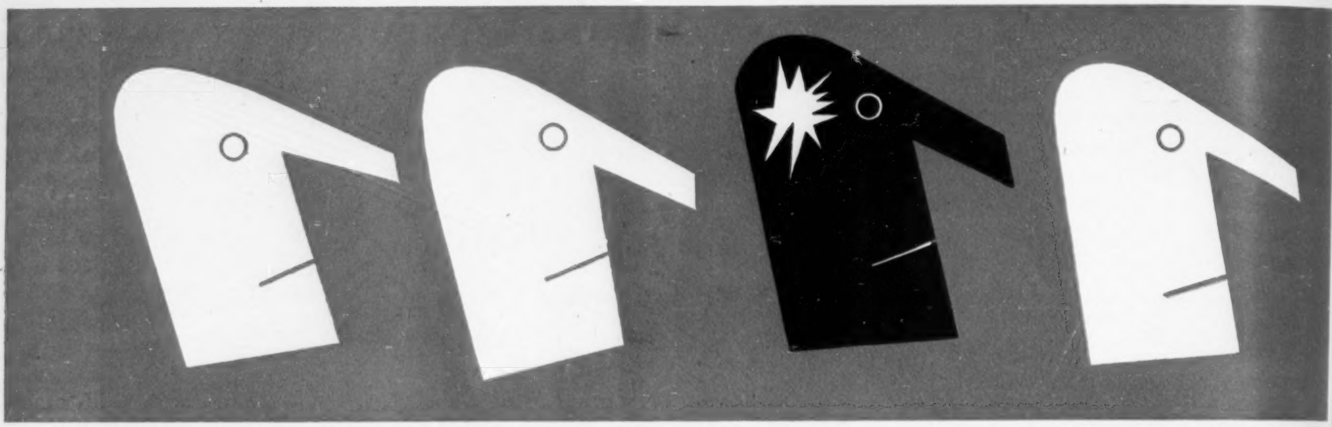
International cooperation in research and engineering through private and free enterprise channels could be a most interesting undertaking. It could well be a venture of lasting significance and benefit to the people of the free world and particularly to the countries concerned.

Harold G. Buchbinder

EDITOR

FOR MORE INFORMATION CIRCLE 5 ON PAGE 48

Studies of individual creativity generally lead to the depressing conclusion that our most experienced engineers and researchers become less creative as they grow older. This report, however, gives us a brighter outlook by suggesting that lowering an R/D team's average age, or varying environmental factors, increases an individual's creativity regardless of his chronological age.



Creativity in R/D Teams

HERBERT A. SHEPARD

This report is based on a study supported by the Social Science Research Council and the Sloan Research Fund of the M.I.T. School of Industrial Management. Other participants included Dr. Lowell W. Steele, Dr. Donald S. Pitkin, Mr. Howard G. Simmons, and Mr. Clare Peterson. Dr. Donald C. Pelz, Survey Research Center, University of Michigan, also assisted in the preparation of the report.

Most studies of creativity have placed their emphasis on the creative individual, and paid less attention to environment factors which may call forth or repress his potential creativity. This approach has produced an iron law of decreasing creativity with advancing age. (H. C. Lehman, *Age and Achievement*, Princeton University Press, New York, 1953.)

The strength of this iron law, however, has been weakened by our studies of research and development teams in a number of industrial laboratories. Ratings by superiors and colleagues of group productivity, responsiveness to challenge and group creativity by the group members were available.

Ratings of individual research workers were not available. However, the relationship between team ratings and certain individual characteristics of members could be investigated. Groups differed from one another in that some were comprised mostly of young workers, and others were made up of older workers. It might be expected that the relation between age and creativity discovered in earlier studies would hold for these groups. Using "average number of years of research experience per member" as a measure of age, Fig. 1 suggests that there is a curvilinear relation between age and performance, with the peak reached after only a few years in research work. For our groups this peak is in the 6 to 8 year class, a finding that corresponds with Lehman's observation that the best work is done by workers in their early thirties.

The results are thus in accord with the hypothesis that research performance rises to a peak in the mid-thirties, and falls off thereafter. Since the ratings are of groups rather than of individuals, however, one might wonder whether the performance ratings are also related to "group age": i.e., the length of time the group members have been working together; Fig. 2 indicates the existence of such a relationship. (Fig. 1 is based on the data—where complete—from 42 groups, two from each of 21 industrial laboratories. The groups ranged in size from 2 to 20 members. Fig. 2 is based on the 35 of these groups whose membership ranged from 4 to 12.)

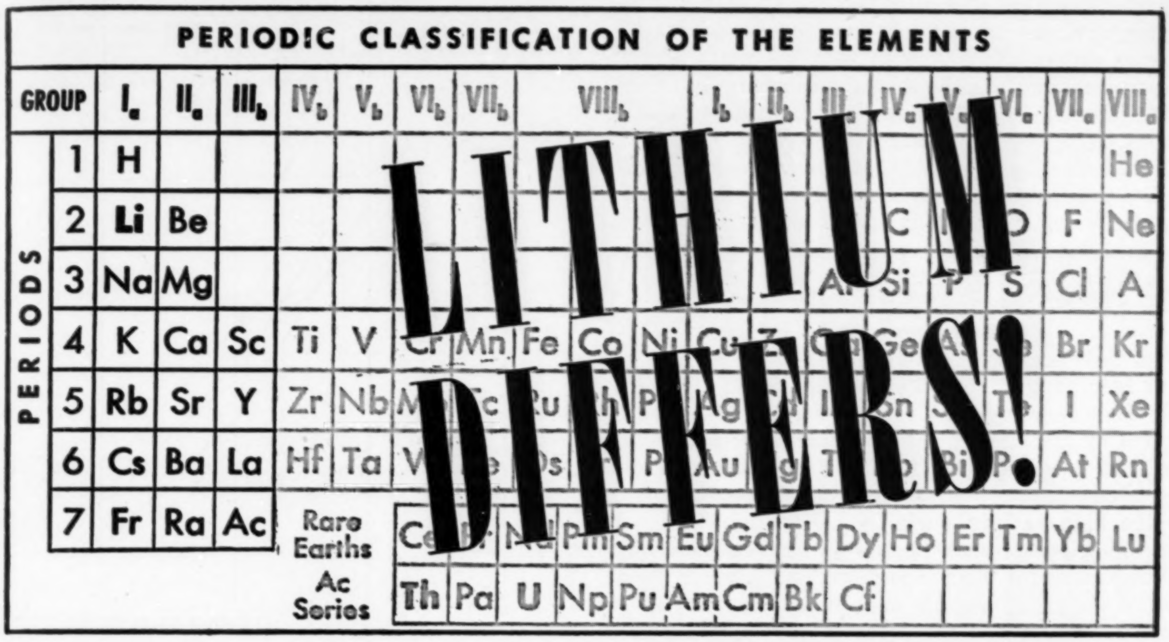
"Young" Groups Do Well

Groups around a year old receive high performance ratings, but with increasing group age the ratings drop off rapidly to a plateau. If there is curvilinearity in this range, it is probably to be found during the first few months, and is obscured by lumping together all groups less than 16 months old. Another way of presenting these data is by comparing high-rated and low-rated groups in terms of group age and total work experience of members (Fig. 3).

TABLE 1

	High Performance Groups	Low Performance Groups	Level of Significance
Number of months "average" member has been in group	30.3	50.8	.02
Number of years "average" member has been in R/D	7.3	9.2	.20

Chronological age and group age are both related to performance, according to Figs. 1 and 2. Table 1 contains the



Lithium, by reason of its atomic configuration and general characteristics, is rightfully included as the first member of Group I in the Periodic Table. A detailed study of the properties and reactions of both the elements and their compounds, however, shows that Lithium often resembles the metals of Groups II and III more closely than Group I. Following are some characteristic differences:

Lithium differs in organic chemistry . . .
because its organolithium compounds form a unique class with stability, solubility and activity characteristics intermediate between those of the Group I and Group II organometallic compounds.

Lithium also differs from the other alkali metals in that it serves as a unique catalyst for the polymerization of diolefins to materials of definite and predictable structure. It directs, for example, the polymerization of isoprene predominantly to 1,4 addition structures.

Again, recent investigations have indicated an interesting potential as a direct reducing agent in solvents such as ammonia, low molecular weight amines, and ethylenediamine.

Lithium differs in metallurgy...
inasmuch as the affinity of Lithium for oxygen, for example, is being utilized to reduce porosity in copper and copper alloy castings. Recent research has revealed that Lithium will produce brazing alloys with self-fluxing properties and increase the wetting ability of these alloys.

Lithium differs in inorganic chemistry . . .
the usefulness of Lithium Hydride and Lithium Aluminum Hydride in the preparation of other hydrides having already been widely demonstrated. Recent studies indicate that other complex hydrides prepared in a similar manner may prove to be interesting tools for research. The low dissociation pressure of Lithium Hydride at its melting point, to cite a specific example, is unique among all hydrides. LiH also has some slight solubility in polar organic compounds which is again unique among alkali metals.

Lithium differs in heat transfer . . .
based on its physical properties it has no equal as a liquid metal coolant. Due to corrosion caused at elevated temperatures by impurities in commercially available Lithium and Lithium Metal, Lithium has thus far found only experimental use.

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FOR MORE INFORMATION CIRCLE 6 ON PAGE 48

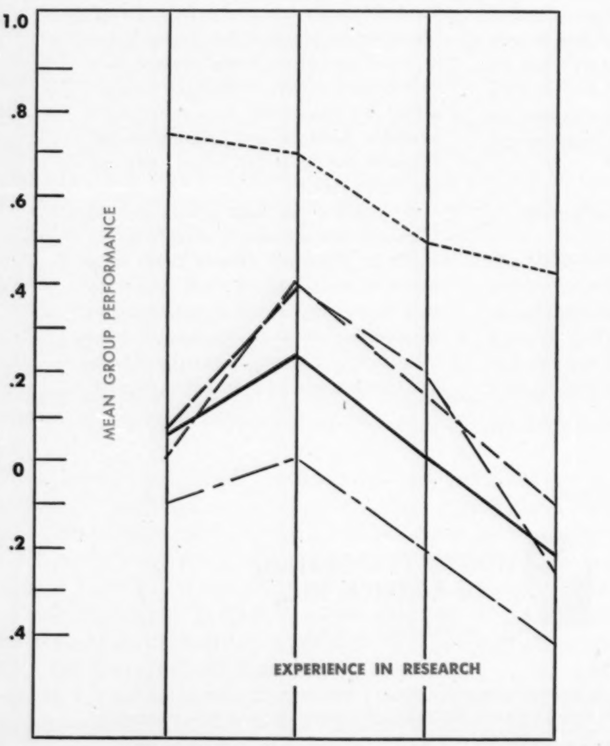
additional hint that group age may be the more important factor. The results of an attempt to discriminate between the effects of the two are shown in Fig. 3. To construct this chart, the performance rating made by each research worker of his own group was compared with his years of research experience, and months in his present group.

In Fig. 3, columns I and II show that, for workers with more than six years' experience, those who have been in their present groups less than 24 months rate their groups significantly higher than do those who have been with their present groups for a longer time. Columns III and IV show that for younger workers the difference is in the same direction, but is not significant. A comparison of columns I and III suggests that the effect of short time in present group is at least as pronounced, or more pronounced for older workers than for younger ones.

We have seen (Figs. 1 and 2) that the shape of group self-rating curves corresponds roughly with the shape of rating curves by management and colleagues. Nonetheless, it may be that the differences in Fig. 3 reflect something more akin to enthusiasm than to creativity or productivity. May not the high ratings made by old workers in new groups be reflections of such factors as respect shown by the group they enter for their experience, or their own overestimation of the group because of unfamiliarity with it?

We have no "objective" measures of performance, but perhaps management's judgment can be regarded as more objective than a group member's. Hence, we may gain objectivity by testing each member's opinion of his group against management's opinion of it. Length of time in group again appears to be the more important factor. In fact, Fig.

Fig. 1: Group performance vs. research experience (average length of time group members have been employed in research work). The key for this chart is in the box at the right.



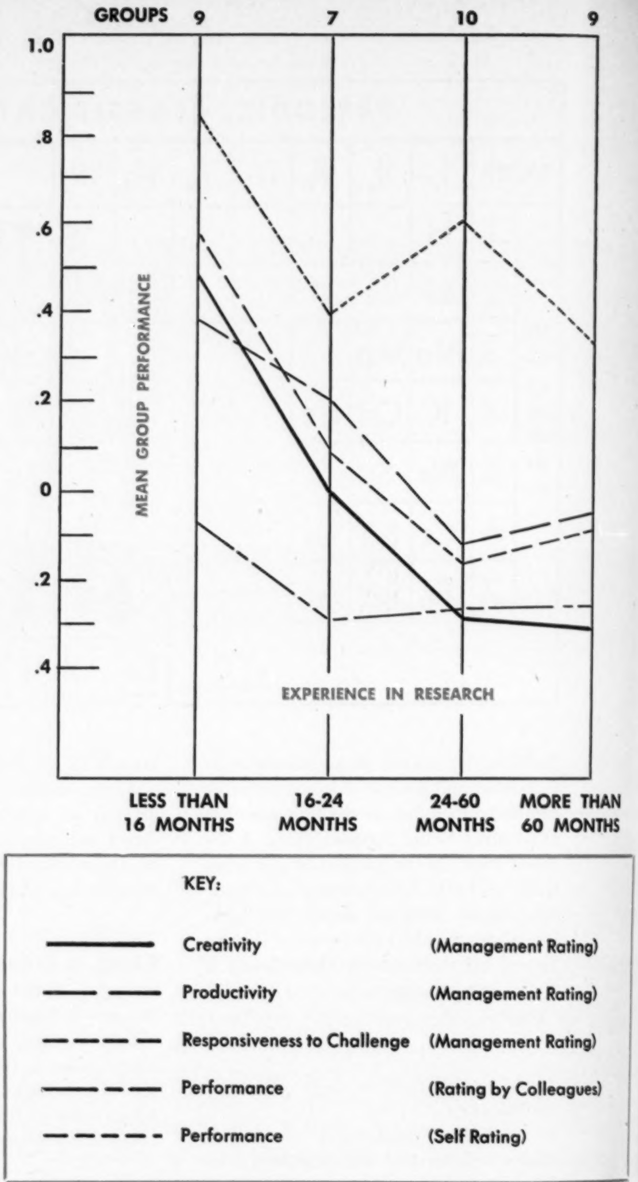


Fig. 2: Group performance vs. group age (average length of time members have been in the group).

3 (management opinion) suggests that there is little, if any, relation between total experience and performance, since the differences between columns I and III, and II and IV, are neither significant nor in the same direction.

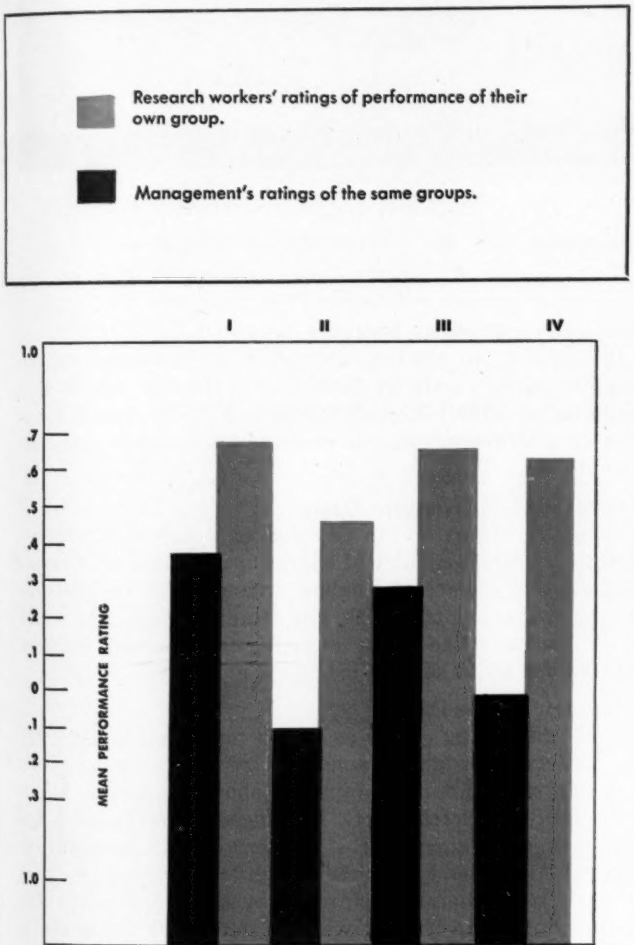
Take Caution

These findings must be cautiously interpreted, as the curves were obtained by making very risky statistical assumptions. Moreover, they are based on subjective performance ratings, and on a population of industrial research groups rather than famous scientists. At the least, they indicate the importance of attending to environmental factors in investigations of creativity. At the most, two generalizations can be drawn:

- The data imply that group age—the length of time group members have worked together—is a factor in group research performance. Chronological age of members appears to be somewhat less important than group age.
- It can also be inferred that new members stimulate and are stimulated by the group they enter. A new member re-

Dr. Shepard began his career as a biologist, expanded into sociology and finally completed his doctoral studies in industrial economics at the Massachusetts Institute of Technology. He is now assistant professor of Sociology, Industrial Relations Section, M.I.T., and also acts as a consultant.

duces group age, and both he and his superiors rate the group high. Perhaps both groups can be maintained at a high performance level by being "kept young"; i.e., by transfers in and out of the group.

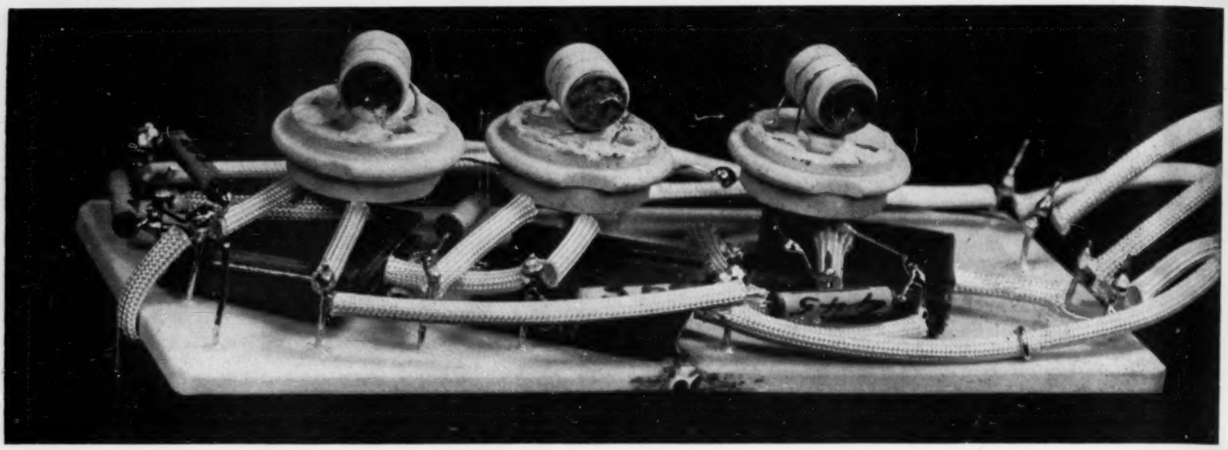


	I	II	III	IV
YEARS OF RESEARCH EXPERIENCE	OVER 6 (MEAN: 14.2)	OVER 6 (MEAN: 12.8)	UNDER 6 (MEAN: 2.8)	UNDER 6 (MEAN: 4.2)
MONTHS IN PRESENT GROUP	UNDER 24 (MEAN: 11.9)	OVER 24 (MEAN: 84.9)	UNDER 24 (MEAN: 12.9)	OVER 24 (MEAN: 41.2)
NUMBER OF INDIVIDUALS	26	52	60	17

Fig. 3: Research workers' ratings of performance of their own groups, by number of years research experience, and number of years in present group are shown in color. Management's ratings substituted for research workers' ratings of their own groups, by research workers' years of research experience, and number of years in their present groups are in black.

FOR MORE INFORMATION CIRCLE 7 ON PAGE 48

Prototype electronic circuit that can operate in over 500°C. Three microminiature ceramic tubes, about the size of pencil erasers, are mounted in the sockets at the top.



Developments

Triumph of the Material designers: 500°C Electronic Circuits

Before aeronautical engineers can send any of their missiles through the thermal barrier, they will need electronic control equipment that can operate at 1000°F. As a result of a nation-wide team effort, the General Electric Company has developed the special circuits that can operate red hot. The many components that make up these experimental circuits are essentially the triumphs of the men who "design" new heat-resistant materials. In addition to the circuits, GE released details of a prototype high-temperature transformer and a servo motor.

Heart of the circuits are the "microminiature" ceramic tubes first announced about a year ago. Now GE engineers have added 500°C resistors, capacitors, wires and printed circuits to mate with the tubes. Added to their ability to withstand high heat, the components are highly resistant to nuclear bombardment and are of simple construction easily adaptable to automatic assembly.

Heaterless Tubes

The circuits were conceived around a tube that could already operate at over 500°C. In the design of the tube, a new ceramic material had been developed with a coefficient of expansion very close to that of titanium. Metal parts of the tube are fabricated of titanium, a metal that *absorbs* gases instead of evolving them. And this gettering action improves as the temperature of titanium increases. When used in circuits at an ambient of 500°C, the tubes don't even require heaters because the right sort of cathode will have sufficient electron emission. One two-tube multivibrator unit was demonstrated in which the heaterless tubes operated at temperatures down to 380°C. The effect could be utilized in many applications in addition to aircraft. For high reliability, circuits such as controls for expensive machinery could be designed with heaterless tubes with the tubes alone mounted in 350° - 400°C ovens.

Microwave Circuits Next

In addition to the multivibrator, a two-stage voltage amplifier with a gain of 1000 and a Hartley circuit that oscillates at 4.16Mc were assembled. Work is now in progress on microwave circuits utilizing these tubes and components.

Resistor with Titanium Caps

James E. Beggs of the GE Research Laboratory developed the resistors capable of operation up to 800°C. Formed on the inside surface of a hollow ceramic tube, the resistive coating makes contact with two titanium end caps sealed under vacuum. The latest resistive films afford resistors with values up to several megohms at 600°C.

Dielectric Materials

After discarding quartz as a high temperature dielectric, the material designers concentrated on alumina. Pure single-crystal alumina—sapphire—showed promise. Meanwhile H. S. Endicott and G. E. Ledges in the General Engineering Laboratory discovered that certain naturally occurring micas could have their high-temperature electrical properties considerably improved by heat treatments. The majority of micas crumble when heated above 500 or 600°C as combined water molecules are released from within the lattice structure. Endicott and Ledges showed that certain domestic micas were not subject to such disintegration when heated and further that the low frequency resistivity of the material increased with such heat treatment.

On the basis of these studies, capacitors have been produced which will operate successfully at temperatures as high as 800°C. Values of 0.001µfd up to 0.01µfd have been prepared by the stacked construction method, and using other geometries, capacitors up to 1.0µfd have also been constructed by the Capacitor Department, Hudson Falls, N. Y. The limited number of materials indicated above does not represent all of the available possibilities, and there is now under way active consideration of other materials. Of course, by the use of ceramic-titanium combinations

Running hot enough to light a cigarette, this servo has a silver rotor and ceramic insulation.

utilized in the vacuum tube, vacuum capacitors can be constructed having low leakage and high breakdown strength. However, because of the unity dielectric constant of vacuum, the maximum capacitance per unit volume is rather small. Such vacuum capacitors will therefore not be feasible for capacitances much in excess of 1000μfd.

Transformers Slightly Heavier Than Usual

Similar in appearance, construction and fabrication methods to conventional transformers, high-temperature types are slightly larger and heavier because the efficiency of the materials decreases at the high temperatures. They were developed at GE's Specialty Transformer Department in Fort Wayne. Substitute materials were sought out because at 500°C copper conductors are made useless by progressive oxidation, common magnetic steels lose their magnetic properties and the resistance of conventional insulation drops to marginal values.

Magnetic steel used in the high-temperature transformers has a Curie temperature well above 500°C; the copper conductors are silver and nickel clad, and the insulation is ceramic. Even these materials experience radical changes in their characteristics from room temperatures to operating temperature. Considerable efforts are now under way to make these transformers practical for production.

Servo Motor with Silver Rotor

Guided missiles passing through the thermal barrier require servo motors in addition to electronic circuts. The Specialty Motor Department in Fort Wayne, Ind., has produced a prototype servo motor that runs in 500°C ambient. Stator insulation is ceramic, the rotor conductors are silver and other conductors are nickel-clad wire. A two-phase type, the motor operates at 400cy and 57v. It is 3½" long x 2"OD. Stators and rotors of similar construction have been operated successfully for 1000 hours at 500°C.

Ceramic Printed Circuits

Ordinary printed circuits would disintegrate long before they are brought up to 500°C. A ceramic base for the circuit was clearly dictated, and fortunately making ceramic bases for printed circuits is already a well-known art. The printed connections are silver. Component loads are spot-welded to platinum supports imbedded in the

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ceramic. Up to 500°C, surface protected copper is a useful material, but for 700°C operation the choice is narrowed to materials such as oxidation-resistant alloys and stainless steels, which are relatively high resistivity materials, and the more expensive noble metals such as platinum, silver and gold.

Cart Before the Horse

The electronics art is now ahead of development of missiles—as far as we know. This means that by the time these circuits are ready to be used in missiles and satellites, they can be completely debugged and production lines set up. This giant step forward could not have been taken by electronic designers without the close support of the men who make materials.

New Military Uses for Ultrasonics

Using ultrasonics for underwater communications at sea and to guard defense installations on land are some of the new military applications for ultrasound proposed by Marcel Collet, a French Signal Corps officer. Writing in a recent issue of *Revue de Defense Nationale,* M. Collet also suggested that ultrasonics can be used to guard against sabotage by frogmen.

A steady ultrasonic signal could be modulated to carry voice intelligence in the same manner as radio waves. Although range would be limited, there is less chance of enemy interception. To protect bases, they could be surrounded by a zone of ultrasonic radiation. Any intrusion into the zone would register on a receiver. Underground installations could also be ultrasonically guarded against toxic smoke and particles, bacteriological or radioactive. According to M. Collet, experiments are under way to determine the effect of ultrasound on explosives. Ultrasonic devices are already in use overseas to explode submerged mines and to guard the entrances to ports or roadsteads.

Selecting Technical Managers

The biggest problem of many an executive today is selecting capable managers to work under him. When he must find a good technical manager he has an out-of-the-ordinary, king-size headache. For this genus is few in number, hard-sought, and particularly elusive. If research and development lives up to its billing as one of the nation's major growth activities (GE, for example, expects its technical leadership jobs to double in the next 10 years), the problem is bound to become even more acute.

Selecting a technical manager is a knotty problem even when no shortage exists. One big reason for this is that many a potential engineering manager won't exert himself to get ready for additional responsibility. Interest must be fostered among engineers in developing, with or without company assistance, any latent managerial skills they may have. Many companies will be obliged to develop within their own ranks the administrative skills they need to head up R & D work. Tied in with this idea is the matter of training young technical men for greater responsibilities as a vital step in the long-term selection process.

At the recent ASME Semi-Annual meeting in Cleveland, A. Pemberton Johnson, counselor and teacher with the Testing and Guidance Division of Newark (N.J.) College of Engineering, suggested one scientific approach to the selection of technical managers. His three-step method involves finding out:

- Key duties to be performed and, if possible, the personal

attributes of men who do them well

- The management "climate" surrounding the position
- What man under consideration has not only best demonstrated his ability to do well the key duties but would function adequately in the climate.

Analyzing Critical Duties

In determining the key duties of a position, Johnson suggests that a method called *critical function analysis* be used. This kind of analysis can be made by one or more technical managers at the level next above that for the position. The basic task is to develop a list of 15 to 20 critical functions expected of the person in that position. Johnson pointed out two possible critical functions of a manager: (1) to supervise design modifications that will reduce production costs; (2) to develop and sell to his superior an adequate budget for the work of his department.

According to Johnson, the first phase implies the encouragement of other engineers to come up with ideas for these design modifications; it carries with it a notion of greater or lesser control over the modifications proposed by these other engineers, and possibly even the setting of standards which will not stifle originality nor allow it to run hog-wild either. The second function, said Johnson, requires an excellent analytical ability as well as adequate foreknowledge of the department's work and the probable turnover of staff.

The Job Description

H. F. Smiddy, vice-president of GE's Management Consultation Services, and B. A. Case, an associate of Mr. Smiddy's, suggest that each manager prepare a statement of his "functions", his "responsibilities" and "authority", his "relationships" or "channels of contact", and his "accountability" to others. He should then explore these with his superior and with those reporting to him. The development of this kind of job description involves analysis and active consideration of the critical functions of the position.

Johnson feels that a properly prepared job description makes clear the management climate of the position. Climate, he says, includes among other things the rapidity with which successive changes in function, organization structure, objectives, and personnel are introduced; the care with which members of the technical and non-technical staffs are prepared for impending changes, the atmosphere of willingness or unwillingness to undertake a calculated risk, the stimulation or lack of stimulation of new ideas, and the upward and downward flows of information.

Developing Managers

To meet the pressing need for technical managers, Johnson advocates a systematic long-term program of fostering the self-development of young technical men toward management responsibilities. He further advocates the systematic try-out and evaluation of these men in positions of increasing responsibility.

Some of the criteria to be considered in judging an engineer or scientist for a technical management position:

- Does he stimulate creative thinking in his men?
- Does he delegate responsibility *and* authority?
- Does he cooperate as a team member?
- Does he exhibit a sound economic sense?
- Does he develop supervisory capacity in selected subordinates?

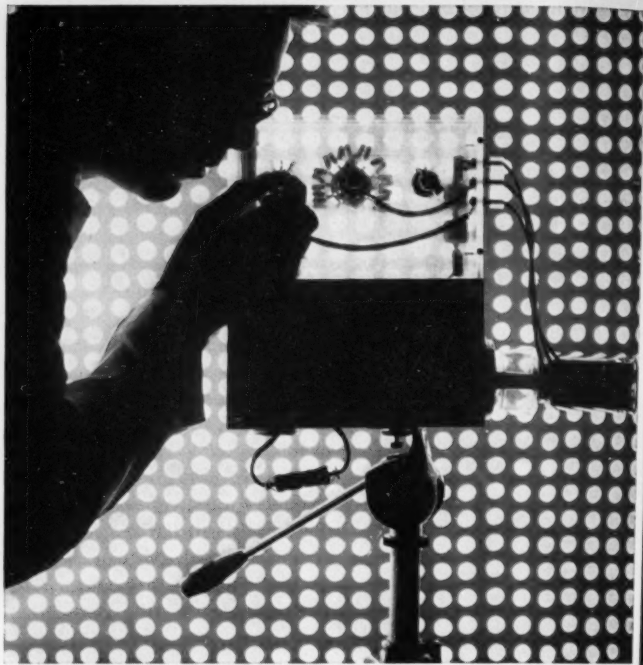
Avoid Irrelevant Selection Methods

According to Melvin W. Thorner, a psychiatrist who spoke at the recent Conference on Industrial Research sponsored by the Department of Industrial and Management Engineering of Columbia University, the selection of technical personnel is a problem with many facets. He feels that all the so-called "objective" testing which has so far been devised is largely futile. Some of the selection process is automatic—that is, only people who want to do R & D are normally assigned to it. Another automatic factor is the natural selection brought about by the demonstration of individual creativity or the lack of it. Thorner says he is satisfied that uniqueness rather than conformity is an asset in the more "fundamental" kind of research activity, and that this may be difficult for the personnel manager to swallow. If irrelevant and misleading personnel selection methods are used, some of this scarce creativity may be wasted or driven to one's competitors.

Thorner says there are two principal ways to promote better R & D in industry: the first and most important is selection of the right personnel; the second is manipulation of the technical environment "climate". His contention is that the main difficulty in selecting industrial researchers is distortion of the process of natural selection by use of some preconceived but inappropriate selection policy.

In manipulating the R & D environment, Thorner claims that it should provide some element of security in the job, in addition to incentives for achievement, both of a financial and "status" nature. And within the organization and without, no artificial bar to communication should exist.

Westinghouse's Investment in Tomorrow



A test pattern background silhouettes the Ebicon, a new television camera tube which operates on a new principle of electron multiplication, promises to be 100 times more sensitive than the standard tube used in television cameras.

Last month Westinghouse Electric Corporation dedicated its new Research Laboratories in Churchill Borough, 10 miles east of downtown Pittsburgh. Located on a 72-acre site, the three-story L-shaped building contains more than seven acres of gross floor area for a staff of more than 700 people. Westinghouse's multi-million dollar laboratory is truly an investment in the future since approximately 30 percent of its effort will be spent in fundamental research, 60 percent in basic research and only about 10 percent in applied research.

Before you get a picture of an ivory tower in the clouds, here are some of the developments that Westinghouse released at the same time—developments that have come from its research group:

- A television camera pickup tube operating on a new principle that promises to be 100 times more sensitive than present-day television camera tubes.
- A new high-temperature, high-voltage insulating material developed jointly with Dow-Corning Corporation that may prove to be worth more than its weight in gold in tomorrow's aircraft.
- An "electronic brain" that may revolutionize the control of complex industrial processes by distinguishing between right and wrong decisions.
- A new rate-type gyroscope utilizing a vibrating mass not a rotating mass as in the conventional gyroscope.
- A full scale presentation of man's newest light source—electronic light—that may eclipse the electric light bulb and the fluorescent tube.
- An electric generator and turbine that operates at 16,000 psi and at a temperature of 1200F.

In addition to these developments, some of which are at the salable level, Westinghouse disclosed some of the work

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TRAINING AIDS

For these projects, Northrop has designed, developed and produced ground handling equipment; electrical and electronic test equipment and related special tools; mobile training units; and simulators for many major weapon systems. Supporting facilities in these latter fields include systems engineering, reliability analysis, design, prototype development, production, field service, and preparation of technical manuals.

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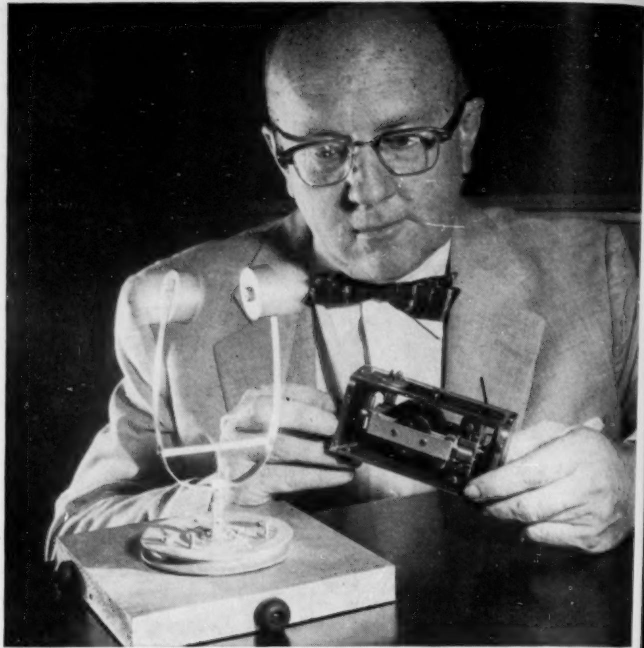


Westinghouse's vibra-gyro bears little resemblance to the conventional tuning fork. Two masses are attached to the sides of a rigid rectangular frame having two heavy ends which might be compared to bases of a double tuning fork arrangement. This assembly is supported by two wires which also serve to isolate the vibrating forces from the base. A small transducer changes the gyroscopic angular vibrations to an alternating electric signal whose amplitude is proportional to the rate of turn. Westinghouse engineers see uses of the vibra-gyro for aircraft and missile applications; its advantages are light weight, no bearings, small size, long life and short starting time.

that it is doing in metallurgy, physical chemistry, electron physics and electromechanical design systems.

Seeing-in-the-Dark

Westinghouse's television camera pickup tube, (Ebicon—from the initials of the phrase "electron bombardment induced conductivity") is expected to be eight times smaller by volume and weight than existing sensitive tubes. This is how it works: As particles of light strike the tube, they produce electrons which are then accelerated by a potential of approximately 20,000 volts. These electrons are shot through the key point of the tube—a "storage target" consisting of a small aluminum coated metal screen and a selenium semiconductor. The "target" serves the dual purpose of storing and multiplying the electrons. This multiplication process generates a signal large enough to operate conventional amplifiers. Some applications for the new tube:

- Military—ability to place enemy troops and movements under closer surveillance during darkness.
- Medical—improve X-ray fluoroscopic techniques now limited by the amount of radiation a patient can stand.
- Astronomy—increase the capabilities to see great distances into space which are now limited by the sensitivity of photographic plates.
- Atomic Energy—it is now possible to detect and measure atomic particles by the scintillation counter.

In the future it may be possible to see and record the results of high energy atomic reactions as they take place inside of luminescent crystals.

Vibra-Gyro

Westinghouse's new vibrating gyroscope operates on a principle known for over 100 years, but for which there were no practical commercial designs available. If this fact is surprising, it is also indicative of some of the problems involved in applying the vibrating mass principle to the design of gyro systems.

The common crane-fly makes use of the gyroscopic forces supplied by vibrating masses known as "halteres" to stabilize itself in flight. Removal of the halteres causes spiral instability and uncontrolled flight in the fly. A simple tuning fork demonstrates the principle of the vibra-gyro. If the fork is turned about a vertical axis with the masses vibrating toward and away from the axis, gyroscopic forces are developed in the form of a couple which produces an oscillating torque about the input axis. This torque produces a small deflection the amplitude of which is proportional to the rate of turn or input velocity. The phase of torsional vibration compared with the phase of vibrating masses indicates the direction of the input velocity.

Solventless Silicone Resin

Westinghouse's new high-temperature high-voltage insulating material can be formed into thick sections of solid, heat-resistant insulation for use in complex electrical gear.

"By eliminating the solvent formerly necessary in heat-resistant resins," said Dr. Lewis, research scientist who developed the material in cooperation with Dow-Corning researchers, "it is possible to produce an insulation entirely free of airspaces or bubbles." Dr. Lewis explained that with previously available high-temperature silicone resins a solvent was necessary to make the material fluid enough for application. However, the solvent often caused bubbles to form as the insulation hardened into a solid form. By developing solventless material, researchers have eliminated this problem and produced an insulation free of bubbles.

The newly developed silicone insulation is another step toward operating electrical equipment at higher output capacity or in higher ambient temperature. Westinghouse thinks that its new insulation will probably find its widest application in the aircraft field because of its ability to operate continuously at 250C for thousands of hours. Dr. Lewis cited an instance in which a class "A" conventionally insulated transformer weighing nearly nine pounds could, by using the new insulation be reduced in size to only four and a half pounds, a weight savings of about 50%.

Computer Tells Right From Wrong

Mathematicians at Westinghouse's research laboratory disclosed the development of "Automex," the computer with a built-in intelligence. The key to Automex's function is that it will, by repeated experimentation, try to reach a given goal with a capacity for dispassionate judgment in distinguishing between success and failure. Dr. Morris Ostrofsky, manager of the mathematics department, explained, "This machine profits from its own mistakes. It has intelligence built into it and decides at every step whether the step just taken was right or wrong. The next step it takes is based on this decision and is the one most likely to lead to success."

Automex was designed to fulfill the need for a machine capable of controlling various factors to obtain a desired result. For example, Automex would be useful to a chemist adding two or more solutions to obtain a reaction in a heated container. The Automex would enable him to find out how changes in the temperature or certain amounts of the solutions would affect the reaction.

In another possible application aeronautical engineers who want to get more miles to the gallon for a jet engine could feed Automex such variable factors as fuel consumption, temperatures, altitude and speed and obtain more efficient operation. Dr. Ostrofsky emphasized that Automex is not limited to control of a process involving only two variables. The scheme is applicable to as many variables as one may encounter in any real process.

Light From An Area

Electro Luminescence—light emission by suitable phosphor powders embedded in an insulator and subjected only to the action of an alternating electric field—was first discovered in 1936 by Georges Destriau, French scientist and Westinghouse Lamp Division Consultant. In its early days electroluminescence was a laboratory curiosity. You had to turn out all the lights and adapt your eyes to the darkness before you could see its faint light.

Now Westinghouse as a result of the work of Edward G. F. Arnott, Lamp Division Director of Research, has panels that are brighter than fluorescent lamps. Because the effi-

ciency of electroluminescence is not yet up to present day light sources, widespread use is not yet economically feasible. "However," Mr. Arnott declared, "if progress continues at the rate that it has during the past two years, practical everyday electroluminescence should not be very far off."

Mr. Arnott stressed that what makes electroluminescence so promising as a light source is the high upper limit of efficiency that could be reached. "This efficiency limit is four times as high as that of today's fluorescent lamp, and more than twice that of the best fluorescent lamps of tomorrow."

Westinghouse exhibited electroluminescent cells of various colors: white, blue green orange and red. One cell in particular was made to change through all four colors by varying the character of electricity applied. Employed on a large scale this principle would permit changing the lighting of a room to any shade of white by merely turning a knob. Psychologically, here are some of its advantages: hot days might appear cooler by using a bluish white; drab and dreary days might be "warmed" by changing the light to a reddish white.

Freeing light from the confines of point or line sources, electroluminescence promises to spark totally new concepts of lighting. Light in the future will be a part of the construction of walls, ceilings and possibly even floors. And because electroluminescence is not restricted to flat planes light may go into the construction of domes, balustrades and other architectural designs.

For the architect and design engineer the opportunities with this new source of light are endless, demanding only imagination from designers and continuing progress from scientists, said Mr. Arnott.

Electricity Directly From Gases

The fuel cell, a battery that produces electricity from such gases as hydrogen and oxygen, is under study at the laboratories of National Carbon Company, Div. of Union Carbide and Carbon. When ultimately developed, commercial fuel cells may be used for reserve of standby power supplies, according to Dr. Robert G. Breckenridge, Director of the new Parma, Ohio, laboratories.

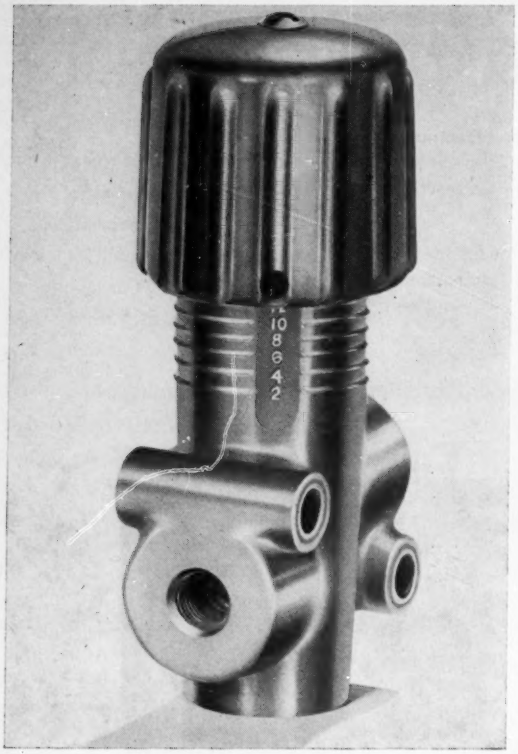
Recent research, both in Great Britain and the United States indicates the new possibility of making a battery which will obtain its energy, its supply of charged particles, entirely from gases such as oxygen and hydrogen.

Dr. Breckenridge says a possible version would include two basic unit sections. One section would consist of layers of porous carbon and a liquid-paste caustic solution with a space between. Oxygen gas would stream into the space, and its molecules would move through the submicroscopic tunnels and channels in the porous carbon.

When the molecules reach the caustic layer they form a film, and reactions take place which produce negatively charged particles. This is the postive section of the battery. The negative section is constructed in a similar fashion. It makes use of a stream of hydrogen gas which reacts to produce positively charged particles.

Fuel cells will operate continuously, providing steady electrical currents as long as oxygen and hydrogen are fed into them. They have many potential applications. For example, they would furnish auxiliary power in chemical plants where these gases are byproducts of commerical processes. Fuel cells could also be used as power supplies for light buoys and remote stations which are expected to run for several years without attention.

COMPONENTS

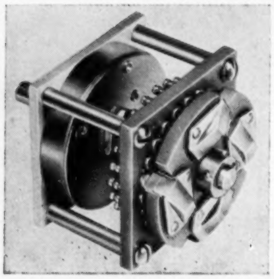


Hi-Temp Plastic Valves

Polyvinyl chloride valves operate to higher pressures and temperatures than expected of plastic valves. Immune to galvanic and electrolytic action, they operate to 170psi, and in lower pressure systems to 170F. Available in needle and globe valve types.

Developer: Chemtrol Corp., 11008 Santa Fe Ave., Lynwood, Calif.

For more data circle 32 on p. 48.



Genuflecting Switch

This knee-action rotary switch can be made in as many decks as required with up to four poles per deck. Capable of several million operations, all of its metal parts are plated to withstand 200-hour salt spray tests.

Developer: The Daven Co., 530 W. Mt. Pleasant Ave., Livingston, N.J.

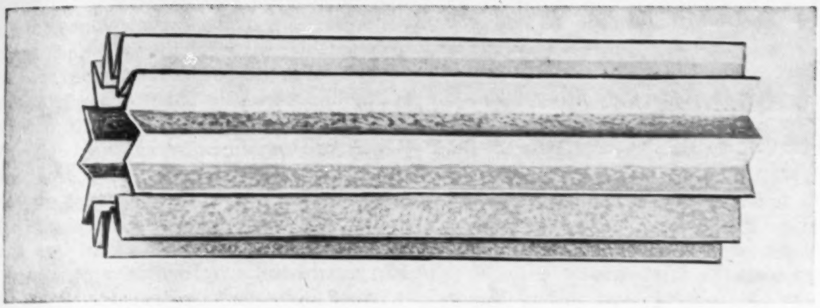
For more data circle 37 on p. 48

Big Blow

Operating at 20,000 rpm, this subminiature blower delivers 8cfm at 1" back pressure to cool electronic equipment in airplanes. Weighs only 5¼ oz.

Developer: Induction Motors Corp., 570 Main St., Westbury L.I., N.Y.

For more data circle 35 on p. 48.

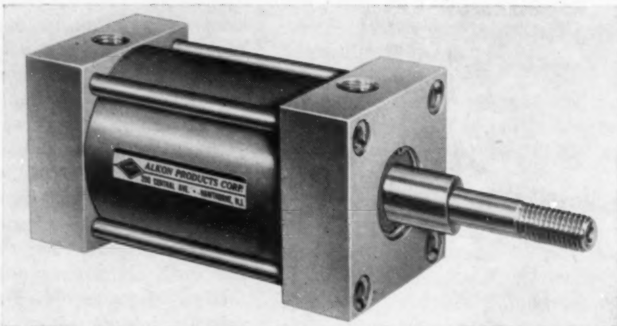


Porous Metal Filter

Made of powdered bronze, these elements filter out harmful solids and contaminants in hydraulic and pneumatic systems. Available in grades of particle-size removal from 2 to 151 microns. Made to blueprint specs.

Developer: Arrow Sintered Products Co., 1944 S. Kostner Ave., Chicago 23, Ill.

For more data circle 34 on p. 48.

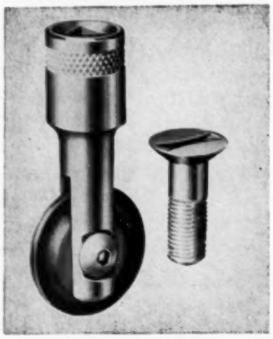


Positioning Device

Intended for applications that require accurate register of the piston rod without cumbersome external guides, this series of double-acting cylinders has an elliptical non-rotating piston rod. Rated 250psi air, 500psi water or oil. The elliptical bushing compensates for eventual wear.

Developer: Alkon Products Corp., 200 Central Ave., Hawthorne, N.J.

For more data circle 31 on p. 48

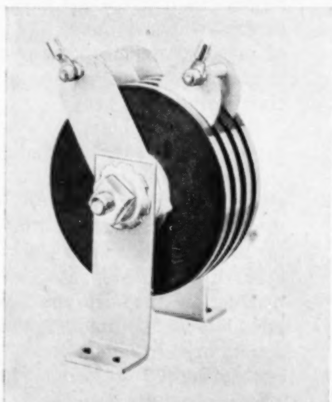


High-Torque Fasteners

New recess design in screws and bolts develops about two times the torquing values normally obtained in turning types of fasteners. Available in special sizes in a variety of alloys.

Developer: Pheoll Manufacturing Co., Aviation Div., 5720 Roosevelt Rd., Chicago 50, Ill.

For more data circle 36 on p. 48



Non-linear Resistor

High inductive surges resulting from sudden interruption of induction currents are discharged by this varistor assembly to protect motors, generators, solenoids, relays and large coils. Mounted for direct installation in circuits, the unit's continuous loss is only about two per cent of an equivalent fixed resistor for the same protection.

Developer: General Electric Co., Detroit 32, Mich.

For more data circle 30 on p. 48.

WEANING THE ENFANT TERRIBLE

HOW TO SET POLICY IN THE GROWING SEMICONDUCTOR INDUSTRY

Abraham Coblenz

One of the pioneers in the semiconductor field, Mr. Coblenz is now assistant to the president of Clevite Transistor Products. He participated in much of the early development work in transistors done by the Signal Corps and co-authored one of the early texts in the field.

In our lifetime, we will see perhaps two or three industries whose rise in volume and importance can truly be described as meteoric. Check off cars, airplanes, radios, TV, antibiotics, vitamins, plastics, frozen foods, and the list of the important, rapidly rising industries is almost complete. And of these, if we arbitrarily set 20 years as a measure of time for growth, only TV, antibiotics, and the semiconductor devices can be said to have a phenomenal growth: from an annual volume of sales of virtually zero, they have mushroomed, in less than 10 years, into important industries.

In 1948, when the transistor was invented, semiconductor diodes, invented about 1906, were not in full-scale manufacture: the field was not reported with the status of an industry, until 1950. In 1955, the annual sales of transistors and diodes were approximately 30 million dollars, (the total in 1956 will be much higher), and the investment in supporting manufacturing operations, research and development activity, capital and associated investments, easily three times that amount —bringing the semiconductor field into the category of a 100 million dollar industry. All this, in six short years!

Tubes, invented approximately 1888, are therefore about 70 years old; transistors are only eight years old and germanium diodes, 50 years old. The tube industry is usually not considered to have come into its own until about 1914. Thus, in six short years, the semiconductor field has come to a sales volume of 30 millions, whereas it took the tube industry 22 years to attain a comparable volume.

It seems justifiable, then, to regard the rise of the semiconductor field as truly meteoric. Having established itself as an important up-and-coming industry, it is profitable to study the problems that confront it and the outlook as I see it now.

The Stalemate

Some of the management problems that confront policy-making managers among semiconductor manufacturers today are peculiar to this new field, but many are found in any industry which has these growing pains and specifically the growing pains of a business that is moving fast. Some problems arise at once because of the nature of the transistor and diode; others reflect the unavoidable vexations in any industry which is new and where absence of previous experience and precedent force the executive to make far-reaching decisions *and then pray.*

One such problem involves the stalemate between the transistor manufacturers and the equipment manufacturers. The equipment manufacturer says, "Yes, I am willing to use transistors, but are you tooled up to produce in such quantities that I am assured of no stoppages on my expensive production line? Do you have a backlog of transistors on hand to take up sudden spurts in my production line resulting from rush orders?"

To this, the transistor manufacturer is forced to reply, "Do you expect me to invest heavily in a production line without definite orders to produce against? And, what will happen to me if, after I am in production, you change your mind and decide to use someone else's transistors or return to tubes for another year?"

This condition, which forced one manufacturer—over 25 years old—out of the transistor business, has plagued the semiconductor industry since its birth and is just now barely being overcome. The solution? It will depend on the individual manufacturer, the size of potential orders or committments, the nature of the production and the time factor.

This state of affairs has seriously impeded the progress of the small semiconductor device manufacturer who needs large amounts of capital to invest; it has also impeded the large manufacturer whose management is understandably wary of large investments in a relatively untried and admittedly difficult business. The risk, as always, must be assumed by the entrepreneur, who in this case is the transistor manufacturer, even in the light of unfrozen designs and ever-changing devices. Slowly, carefully and with as many hedges as they can muster, the transistor manufacturers are beginning to give ground. They are embarking on extremely expensive capital, labor and materials investments to provide the production capacity and inventory that will remove one of the remaining reservations to the unlimited use of transistors in commercial equipments. But, once they get over this hurdle, watch their smoke! Transistor sales in 1956 are expected to triple those of 1955.

It may be well to note that successful companies in this field—Western Electric, General Electric, Raytheon, Sylvania, Clevite Corporation, Thompson Products, Texas Instruments, Hughes Aircraft—to mention a few, never make such investments lightly. Their actions must be regarded as unmistakable confidence in the future of this field. Many have important tube investments to diversify against.

Backing The Right Horse

Today, no one seriously questions the desirability of going into the manufacture of transistors and semiconductor diodes. But, with the vastness of the electronics industry reaching all over the world—applications of transistors and diodes extending from toys to national defense, from sub-oceanic detectors and analyzers to satellites, from transmitters imbedded in golf balls to great, complex computers—comes the inevitable problem of what designs shall we freeze, and determining which of the many immediate applications represent merely a passing fancy. In a field as new as this one, a crystal ball is necessary in deciding which of the current types in production, including JAN and Radio-Electronics-Television Manufacturers Association types will become standard, like the *24A* tube or the *80*, and later the *6SK7* or *6AU6*. And which, blossoming briefly, will become obsolete, like the *35* tube, or the *58*, and others.

Yet, on a policy level, an incorrect decision can be disastrous. Is there a solution? Probably no absolutely sure-fire one, but here are some guidelines that have been found useful.

- Set up criteria whenever a new type, or design, or product is proposed, at least to the extent that someone in a responsible and experienced position has considered several of these. It is probably more important that a large number of criteria be considered for each new project or design proposed than that we try to make sure that the criteria considered are both necessary and sufficient. Twenty-five such criteria are given in the table. A weighting number is given beside each to be assigned according to the judgment of the evaluator. The total is a useful comparison number for priorities. Experience with this list has shown that the numbers used or assigned represent an importance which is secondary to the principal desideratum—that all the important aspects which should enter into the decision have been considered. These considerations assume that the purely technical characteristics are satisfactory. If a New Products Committee is available within the company, a reading of these 25 items is frequently enough to help reach a dependable conclusion.
- Clarify your thinking by setting aside some propositions that seem quite certain, then some that involve more risks with a corresponding increase in potential profit. And finally those items that clearly represent a known risk but involve a handsome profit if successful. By so subdividing these knotty problems one can select items at policy level so as to hedge the risk in some projects by the relative certainty of others. Then the undertaking of those risks that fail from unforseeables will at least not lead to major disasters.

What's For Sure?

Is there anything that is "for sure" in this rapidly moving and rapidly changing industry? Many people believe there is. For example, any management program directed toward improved reliability under temperature, storage and other environmental conditions, is bound to bear fruit and involve no important risk that it is merely a passing fancy. True, the profits are not immediate from such a program and the results take a long time to make themselves felt. But, it's a safe bet.

Any program in the direction of increased frequency of response for transistors is considered reasonably safe, because the present upper limits of frequency for transistors are considerably below those for tubes. Here again, profits will not be immediate and the investment subtracted from the return may or may not be considerable. But it's a safe management program. The recently introduced diffusion method seems to point to transistors of markedly improved frequency response.

Many believe that silicon, already one of the dominant materials for transistor and diode production, may be regarded as "for sure" because of its superior temperature characteristics compared to germanium. Certainly, interest is growing in silicon although it is reasonably clear that the advent of silicon does not mean the abandonment of germanium.

If already in production, any improvements in the reproducibility with consequent improvement in the yield is a safe bet, as it is in any manufacturing operation. A major difference here is that in semiconductor devices increasing reproducibility is usually a problem of great difficulty and may call for much research.

Also in the "for sure" class is the volume market. Again, as in many other manufacturing businesses, the profits are in the volume, not in isolated sales even if these are at high profit per transaction. This market is, of course, difficult to reach for the small manufacturers without financial depth because it is predicated on substantial investments in production and capital equipment. While the small volume market has its advantages—small investment, possibility of rapid changeover to improved devices, smaller risk—it is not considered ideal for the serious manufacturer. Another problem in the volume market approach is that, in this virgin field, your organization may be forced to develop new markets. This is of course expensive and time consuming, but if it pays off, it pays off handsomely.

To the extent that anything is "for sure" in business, these management programs may be considered safe for the long pull in this specialized field. Of course, they presuppose a fairly substantial investment, recovery of investment at best over the next five years and an unavoidable support of the research program. But, for the manufacturer who intends to stick it out, instead of aiming at the fast buck, they are almost "musts".

Good Short-Haul Bets

The portable radio market, including the auto radio market, is, of course, the natural volume market for transistors, particularly the low-power level variety (rated at about 50mw). The difficulty here is that it depends to some extent on the whim of the public, like catering to a new fashion. Also vexing, is the fact that this is no news to anybody, so that really stiff competition can be expected. Here again, the serious, long-term manager must get his engineering team to roll up their sleeves and aim for the biggest part of this known market they can manage. This market may well be a testing ground for our sales staffs.

Then too, like so many markets, transistor portable radios will saturate in two

or three years and the striking upward slope of sales with the months will decrease, approaching a plateau similar to that approached by the sales of the small-tube radio sets. Many will recall that when the midget radio first hit the market in the early thirties, the annual increase in sales was phenomenal for about two to five years and then the market saturated. Of course, these little receivers are still a major income producer, but the spectacular rise is gone. One can confidently predict a somewhat similar cycle for the transistorized receivers, both of the ac-dc type for the home and the battery-operated portable.

For immediate return, for the manufacturer geared to produce good quality transistors in high volume at competitive prices, portable radios should be a good bet for the next few years; and, of course, there is always the replacement market. We are about five to seven years from the stage where people will throw the old transistor set away as soon as it stops working and buy a new one. The radio repairman will be with us for a long time.

Bet on Germanium Diodes

Another good bet, with proportional risk, for a continuing demand in an intensely competitive field, is the germanium diode. While germanium diodes will unquestionably remain salable items for many years, the constantly changing designs, revisions, variations and applications deny this field the stability of the "for sure" items. Both in the low- and high-power ranges, diodes promise to keep the tube and selenium manufacturers in a sweat for some time to come. The executive who believes that germanium will be thrust aside entirely in favor of silicon should consult his technical and sales staffs. Mature thinking in this field indicates that silicon will not replace germanium entirely because:

- Germanium diodes are capable of forward resistances markedly less than for silicon under comparable conditions. For power diodes, this factor alone may be deciding because of increased efficiency.

- For the next few years the price of silicon, and of devices made of silicon, will be greater than for germanium under comparable conditions, because of the higher temperatures needed for silicon treatment and other difficulties in fabrication of silicon devices, such as contamination.

- There are many applications where the essential features of silicon devices, namely, capability for higher temperature operation and higher inverse resistance, are unnecessary. Having started with germanium and finding it satisfactory, manufacturers will not be panicked into silicon to the total exclusion of germanium without sufficient cause. Germanium diodes have been the "bread and butter" of many organizations in the solid-state field, and the number of applications is so large that it seems a good bet that they will not be displaced in a twinkling. Remember, the radio did not sound the death knell of the phonograph record, and TV did not sound the death knell of radio.

Then, there is a long list of devices which represent a short-range income producer, soon to be replaced by something newer and better. The second detectors and mixers, the high frequency diodes, the general purpose diodes, the "high frequency" transistors (the concept of what constitutes high frequency is continually changing), the photodiodes and phototransistors, the u-h-f diodes, and the various special purpose diodes and transistors that might sell 10 million, but may also not sell beyond the sample 25. In this last category, there are no guide posts, almost no rules, no wisdom based on experience.

The Marriage of Business and Research

Standing off to one side of the hectic business that is semiconductors, like a philosopher pondering the maddening crowd, is the indispensable research team. It is paradoxical but true, that the most constant and reliable aspect of the transistor and diode field, particularly in the manner it affects scientific research and management policy, is the constant state of change. It would be a management blunder so grotesque that probably no one has yet committed it, to assume that the semiconductor field is anywhere near stabilization. And this concept, because it is so axiomatic and obvious, is useful as a guiding stone on this strange path that we creep along. For, it indicates that without an R/D team, management cannot conduct a transistor and diode business. For even if you decide to turn jobber and merely buy from the manufacturer and sell to the user, you will find that a knowledge of applications is indispensable to sales.

The moment you find this out, a research team will take birth in your organization. Long established rules about fixed percentages of sales being used for research are almost useless in this virgin field, where almost everything you do has an element of newness. A company deriving its income from transistors and diodes alone could not manage on the two to five percent of sales usually allowed. The situation here is entirely analogous to the vacuum tube field in its early days save that in semiconductors the pace is faster. Just as vacuum tubes came from the audion, through the *WE-11, 201A, 26, 24A* to the *6SK7* and *6AU6* development, in a period of some 50 years, transistors have already come through the type *A1698, 2N21* and in-line structure to the subminiature transistors; and from the early *1N35* and *1N69* to the *1N301* and *1N460* of 1956. And of course this is only the beginning. Hence, the unavoidable conclusion: you either stay in the transistor and diode business and plow a significant portion of your profit and investment funds into R/D, or you make up your mind to go into another field.

This marriage of business with industrial research has become increasingly common in the last 50 years. Industry has learned that research can increase its profits, sometimes spectacularly, and the marriage has turned out to be a successful one. The researchers, on the other hand, have come to realize that without the financial support of business, their research proceeds rather slowly and painfully.

Even with the limited experience gained with the 30-odd companies now in this field, it is already apparent that without a sound R/D program, a company can fall so far behind that it must leave the field. The best that management can do is to channel a large part of the research budget into directed projects leading to desired results, and a smaller portion to basic research.

But, experience shows that even this formula must often be waived. Frequently, directed research, initiated to solve an important production problem, shows incontrovertibly that the answer required can be obtained by a program of advanced research only, and by that time there is no turning back. Nor, when assigning a directed research project, can you tell a man, though he be the most brilliant scientist, to go and invent something. Frequently, one can accelerate development by vigilant management and a program of incentives, but when it bogs down in a problem involving basic unknowns, management must retreat from the laboratory.

What About the Future?

While no one pretends to be able to predict the course of this rapidly changing, dynamic little industry that's growing like Topsy, few remain who question that it is destined to greatness. Applications like single-station receivers in flashlight cases, guided missile electronics systems, a host of possible medical applications, motors (commutation), miniature receivers, transmitters, paging systems, walkie-talkies, represent uses for transistors and diodes that are innumerable in the future. The application of semiconductor materials into all manner of futuristic contrivances (television screens, large-area lighting, pressure indicators, temperature sensitive devices, radioactivity detectors, computers), further extends the possible boundaries of the general field. The possible uses of a device that will amplify or oscillate and which is tiny in size, weight and cost have convinced companies from the multibillion dollar ones to the shoe-string newcomers that transistors and diodes are really forerunners of even greater solid-state devices to come.

For we are by no means to be limited to germanium and silicon. Farsighted management, all around the world, is putting a teenie-weenie amount of money into the intermetallic compounds — those endless combinations and permutations of two or more elements which under special conditions produce semiconductors. Some, like indium antimonide, have already received much attention and investigation because of high frequency and other special appli-

cations. When one contemplates the possibilities in these binary, trinary, or ternary compounds, the problems of management in deciding long-term company policy assume staggering proportions. For management will forever be called upon to answer the burning and risk-laden question: Which horse shall we put our money on? Lady luck stands on one side and bankruptcy proceedings on the other. As an illustration of management headaches: A newcomer now in focus is the diffusion transistor which, according to some sources, may replace our present grown and alloyed transistors.

General Management Policy

In this inscrutable, ever-changing, highly competitive, and technically advanced field, what shall be management policy? Two facets we have already seen: The constant change and the indispensability of the R/D team. The corollaries to these are, of course, the periodic re-examination of policy in the light of new developments and markets for the first, and the nurturing of a highly skilled research team in this new field for the second. Because of the industry's youth, physicists, chemists, metallurgists, and engineers with long experience are hard to come by and very much in demand. The stage seems to indicate, then, that a management-inspired training program for junior scientists is imperative. We can cite here the analogy with electronics and vacuum tube experience again wherein many concerns, notably RCA and Western Electric, have for many years had such training programs as standard company policy.

Beyond these two and their corollaries, management must lean on the universality of management procedure: what constitutes good management practice in one field will probably be just as good in another, though they are quite different fields. Common sense, good labor relations, progressive personnel policies, study of new markets, a balanced team in sales, accounting, engineering, manufacturing, and administration—all these you have heard before in connection with other lines of industry, and they carry over virtually intact. One must never assume that because the item handled is radically different, the management policies must be radically different. If this is true at all, it is true in one or two aspects only, and even in these there are probably related areas where even this difference becomes small. One of these differences, to cite an example, is that in the semiconductor field significant profits from operations have not been possible until quite recently because of the research and development that have had to accompany each new sales item.

A management consideration in the transistor field that must also receive detailed consideration is that connected with government contracts. From 1951 through 1953, when the commercial market for transistors was virtually nonexistent, the government supported research and development and early attempts at production in the transistor and diode fields to shorten the time cycle normally required for a new item to become military useful. It was quite clear that on their own, progressive manufacturers might enter the field; but without substantial markets their investment and progress might be no greater than it was in the early vacuum tube days. And this is too long to wait in these times.

GUIDE FOR SETTING POLICY

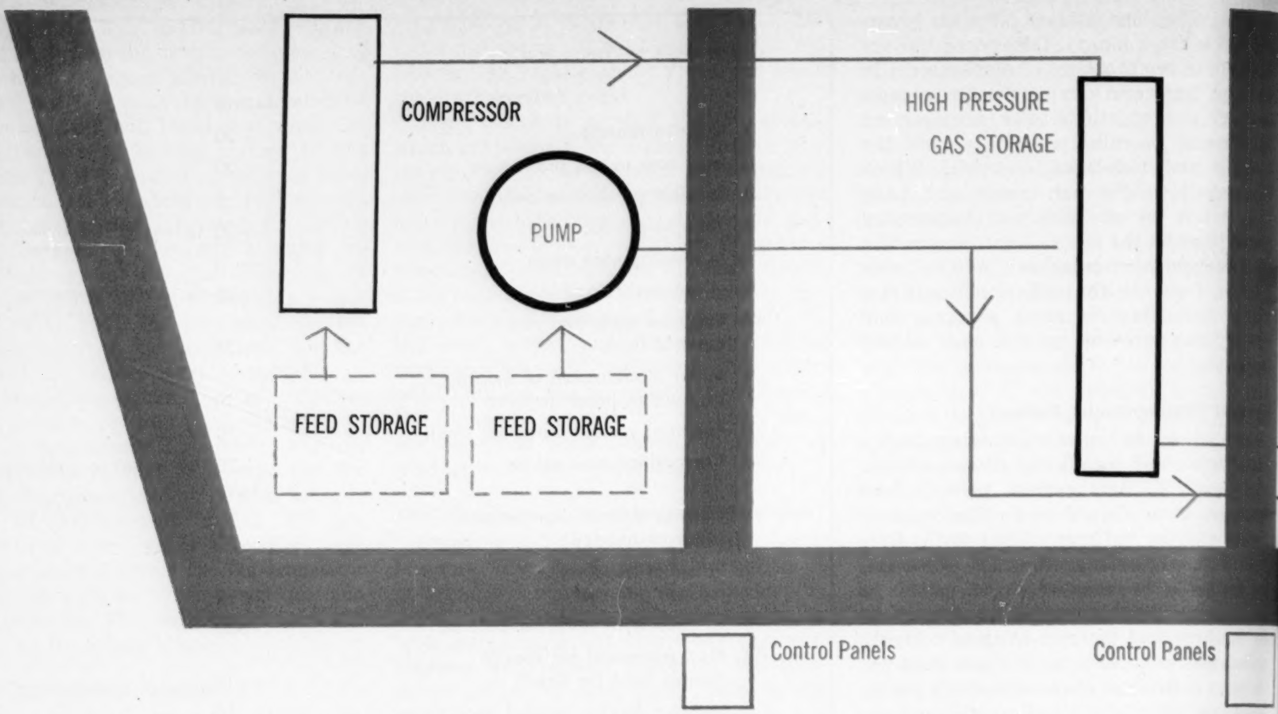
FACTOR	RATING
1. Captive market	+20
2. Item now in full production	+20
3. In pilot production only	+ 5
4. Time to produce	+20 to —10, depending on time
5. In development stage	— 5
6. In research stage	—10 to —20, depending on time
7. Requires entry into new general field	—20
8. Minor modification of existing production items involved	+10
9. Potential market large or small	+20 to + 5
10. Competition now extant	+20 (for none) to —10 for keen
11. Time to deliver short (crash program needed)	—20
12. Potential industrial or military contract	+10
13. In interest of national defense	+30
14. New personnel for special project must be hired	—10
15. Involves foreign market operations	—10
16. Involves heavy patent royalties	—10
17. Requires investment	—20 for very heavy investment, to 0 for modest.
18. Market uncertain	—10
19. Credit rating of major customer poor	— 5
20. Creates major new distribution problem	—10
21. Involves item now sold by important company customer(s)	—20
22. Production facilities from other source available	+10
23. Pet project of VIP	+10
24. Requires basic research	—10
25. Requires extensive customer education or changeover program	—10

The Baby Has Been Weaned

Accordingly, the Government, particularly through the Signal Corps, supported substantial transistor programs with Western Electric, General Electric, Radio Corporation of America, Raytheon, Sylvania, Clevite, Hughes Aircraft, Texas Instruments, Transitron and others. This support is still significant and still essential, but having put so many companies on their feet in this new field, the government can now lean back a little and be sure that the essential work will be carried on somewhere. The government-supported contract is now used more in the nature of a lure to induce companies in this field to enter areas where immediate commercial applications are not evident and in which they might otherwise be reluctant to invest their research and development capital. Accordingly, today management keeps one eye on possible items that may be interesting to the military and which may lead to government support. The profit in such government contracts is negligible; the plum is actually the know-how, equipment, experience, and trained personnel.

The semiconductor industry is today entering a more productive and profitable era. The period of preparation, with government support, is beginning to produce items commercially and militarily salable, markets are expanding and production rates increasing.

Here we go! END



In 10 years chemical processing at high pressures and temperatures has grown from a closely held laboratory art to a mass-production tool. As a follow-up to our August issue on the state of research at high temperatures, here is a survey of design and material selection problems for continuous process reactor for high-pressure, high-temp service in the chemical and petrochemical industries.

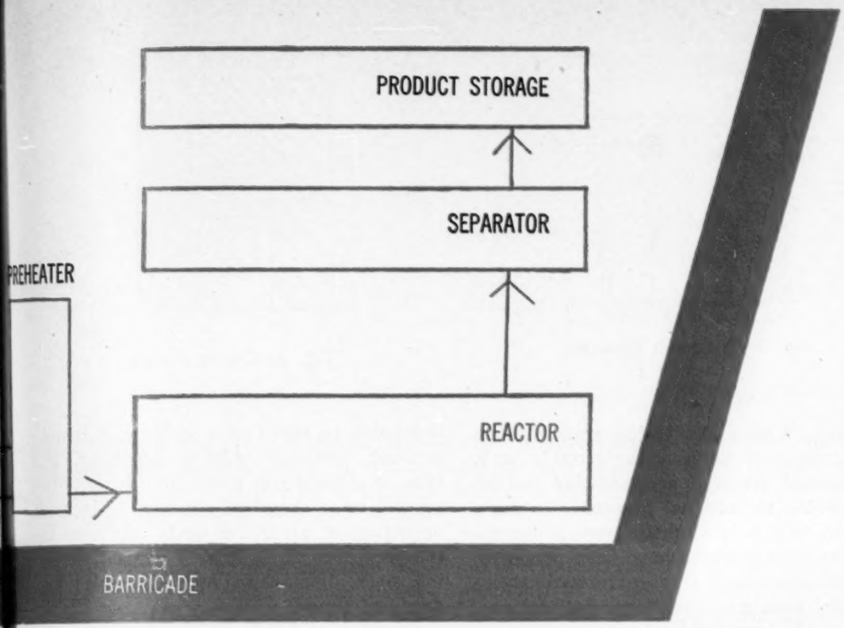
Research and development in chemical processing at elevated pressures and temperatures has increased markedly in recent years. Whereas only 10 years ago activity in this field was almost entirely confined to a few laboratories which were knowledgeable in the secret art, today numerous industrial concerns are deeply involved in well-integrated basic research programs to exploit the possibilities in this fascinating field of chemical processing. The magnitude of this growth is evidenced by the number of companies that today mass-produce equipment which previously had to be fabricated on special order.

The problems involved in continuous chemical processing at elevated pressures and temperatures are quite different from fundamental studies on the behavior of matter under extreme pressures and temperatures. In chemical processing the equipment inherently must be of relatively large capacity, it must operate in a continuous flow system over long periods of time, and it must be amenable to frequent dismantling without deleterious results. For these reasons, it is not possible to utilize the full metallurgical limit imposed by the materials of construction. Although pressures in excess of 1,000,000psi are not uncommon in fundamental research studies on the properties of matter, applied research on chemical processing is usually limited to pressures substantially below 100,000psi. The most severe limitation on pressure in this case is temperature, which above 1000°F introduces serious problems associated with creep. A typical rule of thumb is that the allowable operating stress is halved for every 50°F rise in temperature above 1000°F. The related factors of time, temperature and chemical processing further complicate the problem by introducing corrosion problems. As an additional aggravation, some of the most corrosion-resistant materials of construction do not lend themselves to economical means of fabrication.

Criteria for Equipment Design

Although the problems associated with mechanical details of fabrication and operation are frequently limiting, initial consideration must be given to the allowable stress levels for the materials of construction in order to assure satisfactory operation. Unfortunately there are no well-founded, simple rules; each situation must be examined individually in the light of desired performance. It is here that experience becomes a vital factor if optimum design is to be achieved.

Generally, the determination of allowable stresses is divided into two categories on the basis of operating temperatures. For temperatures below which creep rates are "insignificant," the allowable stress is usually taken as some fraction of the yield strength (0.2% offset) or the ultimate strength. There is no clear-cut, rational basis for selecting one criterion as opposed to the other. The ASME Code utilizes a factor of safety of four based on the ultimate. However, this code covers only a limited number of cases in the lower stress range; for most cases of present interest in high pressure research, the application of the Code leads to absurd results, which would preclude much of the equipment in operation today. In high pressure work the so-called factor of safety is merely one of expedition, the philosophy being to utilize the largest factor consistent with establishing the permissibility of a design to meet specified conditions of operation. For example, one suggested rule is to use a factor of safety of 2.5 based on the yield when designing for 20,000psi; 2.0 for 50,000psi, and 1.5 for 90,000psi. Obviously, this recommendation is intended to extend design limits as far as possible; as pressures above 90,000psi find more application, the factor of safety will probably be reduced correspondingly. Basically there is no justification for holding the factor of safety to some value below the yield strength; it merely provides some latitude for such ignorance factors as stress concentrations, non-uniformities in the properties of construction materials, etc. In fact, it has been hypothesized that regardless of what safety factor has been



High-Pressure, High-Temperature chemical reactors

P. A. LOBO and C. M SLIEPCEVICH

used to establish the allowable stress, the inside bore of a pressure vessel always attains its yield stress value as a result of these indeterminate factors.

Above the temperature where creep becomes "significant," the allowable stress is dependent upon the amount of permanent deformation permissible before the equipment becomes inoperable or the operating life desired previous to failure. A general rule is that the operating stress should never exceed the stress causing a creep of one percent in 100,000 hours or a stress which produces rupture in 100,000 hours, whichever is less. Here again, these rules are frequently stretched in specific situations.

The strength properties of materials of construction are most readily obtained from measurements in simple tension or uniaxial loading. In application these materials are almost always subjected to multi-axial stresses. However, using the results from a uniaxial test for a multi-axial stress application is conservative since the latter gives a lower creep rate and causes rupture after a longer time than a corresponding uniaxial loading. The degree of conservatism is difficult to estimate because no one theory of combining multi-axial stresses into an effective uniaxial stress is applicable to all materials of construction. Of the many theories that have been advanced, only three seem to be in reasonable agreement with limited experimental evidence:

- Maximum Principal Stress: The largest principal stress determines failure. Stresses in the other direction have no effect. Cast irons seem to follow this theory.
- Maximum Shear Stress: The failure of a material depends only on the maximum shearing stress that is attained. This theory is in good agreement with steels.
- Huber-Hencky-von Mises Theory: This theory assumes that only the energy which causes shearing deformation is responsible for failure. Except for very brittle materials, this theory predicts failure more accurately than any other.

Since brittle materials (less than five percent elongation) are not used for members in tension, and since for pressure vessels an elongation of 15 percent is desirable, either the maximum shear stress or von Mises theory are usually adequate.

Selection of Materials of Construction

Hard and fast rules are not available for choosing materials of construction for high pressure equipment, as each application must be evaluated individually. Conditions of operation, desired service life, and the chemical service to be encountered must all be considered, and here past experience with an alloy under similar conditions is valuable.

The alloys most commonly used are the types 300 and 400 series stainless steels and AISI 4340 steel. The type 300 series has a minimum yield of 35,000 to 40,000psi and can be cold worked to obtain higher yield strengths. The type 400 series and AISI 4340 are heat treatable and a yield as high as 150,000psi at over 15 percent elongation can be obtained in this manner.

At temperatures much above 1000°F, the creep and stress rupture strengths of these alloys are too low for use in pressure equipment as the advantages gained by heat treatment and cold working disappear in this range. Duplex construction and autofrettage cannot give increased strength at the high temperatures as plastic flow of the metal eliminates the advantages gained by superimposed stress distribution. Consequently, one must utilize the high temperature alloys or superalloys. Unfortunately, many of the superalloys are unsuitable for fabrication of pressure vessels with present day techniques. A few which have been used successfully for this purpose are 19-9DL, 16-25-6, N-155 and Inconel X, although fabrication with these alloys is more costly than fabrication in the stainless steels.

The effect of the chemical environment on the metal must be seriously considered as corrosion may be much more severe under extreme pressures than might be anticipated from data obtained under similar conditions but at atmospheric pressure. The tendency for stress corrosion cracking to take place in stress-corrosion-susceptible metals is greatly increased at extreme pressures. Extreme care should be excercised in choosing materials

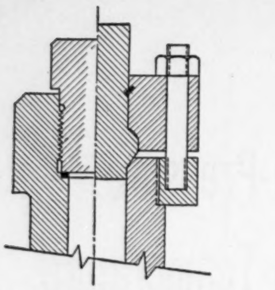


Fig. 2. Compression-type closures.

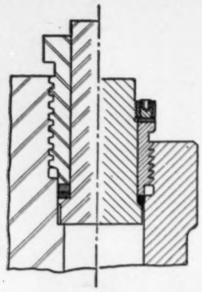


Fig. 3. Bridgman closures.

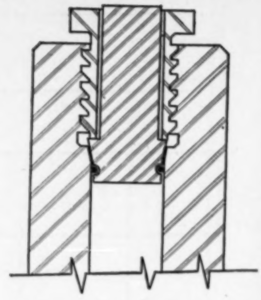


Fig. 4. O-ring closure.

to handle hydrogen and carbon monoxide at high pressure due to the peculiarities of their attack. Recent data have shown the austenitic stainless steels to be quite resistant to hydrogen attack at a pressure of 30,000psi and 900°F.

Design Formula

The design of a pressure vessel is usually based on the premise that none of the stresses should exceed the elastic limit. This restriction can be attributed to a certain amount of ignorance factor in that it is possible to compute elastic stresses in the walls of a pressure vessel, for example, within a reasonable degree of accuracy, whereas plastic stresses involve a degree of uncertainty. It is ironical that the equations of elasticity are supplied to situations where plastic deformations or creep are limiting factors. Empirical approximations for alleviating this paradox have recently become available, although these methods have not received widespread acceptance as yet. The usual procedure is to utilize the Lame solution of the elastic equations to determine the principal stresses. The three principal stresses are then applied to one of the failure theories discussed above, preferably the von Mises' theory, to determine the geometric proportions. Usually, only the stresses at the inside bore, are calculated since both tangential and radial stress are a maximum at the bore and axial stress is independent of radius. It should be realized that this design is based on the maximum equivalent stress which occurs only at the inside bore and this stress decreases markedly as the outside radius is approached. A more economical design, which is still within safe limits, might be based on some intermediate radius where advantage could be taken of the support provided by the outer layers of the vessel wall. However, to date, there is not sufficient experimental evidence to define such an intermediate radius.

Because of the uncertainties involved in establishing allowable working stresses, various simplified formulae are used by designers. One example is the Barlow formula which gives slightly conservative results. In the design of flanges, a variety of formulas are available.

The stresses arising from large temperature differences across thick walls can be appreciable and consequently should be evaluated. Where the inside wall is at a lower temperature than the outside wall, the thermal stresses are additive to the stresses due to internal pressure. Luster's equation, which is slightly more conservative than others which have been proposed, in combination with straightforward stress analyses, should suffice for most designs. It must be remembered, however, that overdesign does not necessarily represent the best or optimum design. Even as much as 1/64 inch, improperly placed, could render a design inoperative. Nevertheless, for inexperienced personnel, the ASME Code should serve as an upper limit.

Obturation of Pressure Joints

In continuous chemical processing, the closure on the reactor is probably the most critical part of the design. It must not only provide a leak proof seal, but it must also continue to give satisfactory performance after repeated dismantlings and assemblies. A variety of closures have been used, but they can be classified into two types: compression and self-sealing. The compression type is seldom used above 10,000psi except for openings less than an inch in diameter. The self-sealing closure has theoretically no upper limit of pressure except metallurgical since the pressure in the vessel is used to obtain a leak-proof seal. However, the self-sealing closure must be machined and assembled with considerable care; otherwise it is difficult to dismantle, particularly after operation at high temperatures.

Closure design has improved markedly in recent years principally as a result of improved materials of construction and increased knowledge in high pressure techniques. A very good illustration of the degree of improvement is shown in Fig. 6. The present-day autoclave, complete, weighs less than just the bolts and nuts in the old design.

The compression-type closure depends on either a gasket or metal-to-metal line contact of mating surfaces for its seal. Fig 2 compares these two principles; the metal-to-metal line contact is obtained by machining the seat at 60° and the plug at 58°. When properly designed, the metal-to-metal joint requires less torque to accomplish the initial seal than the gasket type. The life of the former can be prolonged considerably by extending the plug beyond the sealing point to serve as a guide and thereby prevent "cocking" during assembly. This type of closure has given maintenance-free service on a chemical reactor, ¾-inch ID, operating at pressures up to 10,000psi and temperatures up to 1100°F even after having been dismantled and assembled hundreds of times.

Closures utilizing the self-sealing principle are shown in Fig. 3. The closure on the left is a full Bridgman whereas the one on the right is a modification. The latter utilizes the line-contact principle on the gas to reduce the torque required to accomplish the initial seal.

O-Ring Closure Popular

Since World War II, the O-ring closure, Fig. 4 has been used very extensively. Although this closure depends on the self-sealing principle, it utilizes the principle of line contact just above the O-ring to prevent extrusion of the ring during operation and thus nullify the need for machining to close tolerances. A number of other designs which make use of the self-sealing principle to some extent, such as the delta-gasket in this country and the wave-ring and lens-ring abroad, have been used successfully. However, from the standpoint of combined simplicity and performance, the O-ring is probably the best closure that has been devised; its only limitation is the materials of construction of the O-ring.

Closely associated with the obturation of vessel openings is the problem of couplings. Obviously, the problems are identical except that the size of the opening that must be sealed in a coupling is much smaller and therefore more easily effected. By far the most widely used type of coupling is the mass-produced, gland and collar fitting shown in Fig. 5a. This coupling has been improved markedly in recent years by utilizing better materials of construction and minimizing stress concentrations by minor changes in the design. The principle objections to this closure are the weakening of the tubing at the threaded collar and at the conical seat. Also, for tubing greater than ¼-inch OD, the diameter of the gland becomes quite large and its threaded portion has a tendency to seize after prolonged operation at high temperatures. Fig. 5b represents a means for avoiding these difficulties. In this design the diameter of the threaded studs need not exceed ½-inch for

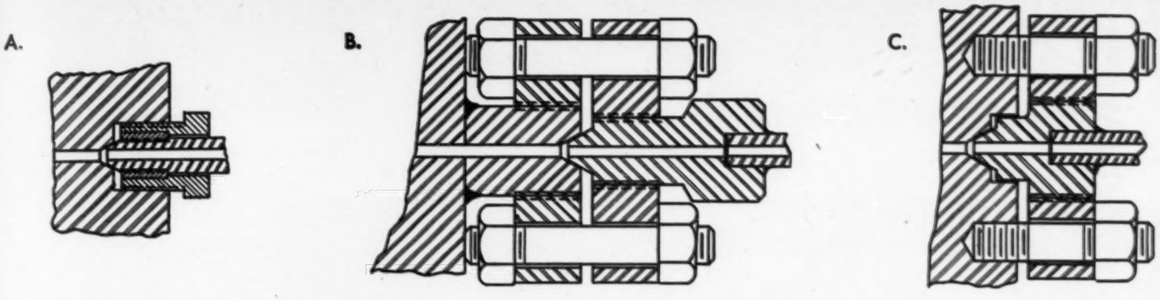


Fig. 5. High pressure couplings.

most applications and thus seizure is minimized. The seal on this coupling can be made by only a half turn with a wrench on the studs. If care is exercised in assembling this coupling to avoid cocking and over-tightening, maintenance-free performance can be obtained almost indefinitely. The coupling in Fig. 5c is a modification of Fig. 5b to minimize welding (where special alloys are used which have poor weldability) and to provide a guide for alignment during assembly. Although the initial cost of the couplings in Figs. 5b and c is substantially higher than the coupling shown in Fig. 5a, the former may be more economical in the long run because of trouble-free operation.

The factor of seizure of mating ports as a result of operation at high temperature can be particularly aggravating and costly. The principle of using materials of different hardness on mating parts cannot always be utilized, particularly if the creep and thermal expansion of these materials are different. Surface finish and cleanliness are extremely important; the additional cost of grinding and the additional time required to prepare clean surfaces prior to assembly are always justified. Lubrication of mating surfaces is required for operation at elevated temperatures. There are a number of excellent lubricants available on the market, such as liquid suspensions of graphite, molybdenum disulfide, copper, silver, and a variety of silicones, to name but a few. Probably more important than the composition of the lubricant itself is the method of application; a thin, uniform coating is required. On threaded sections coarse threads and Class 2 fits are recommended, but care must be taken to maintain the pitch between the male and female threads within close limits. The use of grinding compounds on mating threads prior to the initial assembly is advocated; on subsequent assemblies it is worth the effort to match these threaded sections. Where possible, the diameter of the threaded sections should be kept below one inch, although this requirement may introduce complexities in design.

Where close clearances are required on smooth, mating surfaces, as in the Bridgman closure, a "running fit" such as a clearance of 0.003-inch on a one-inch diameter section is usually sufficient to prevent seizure, and at the same time the clearance is small enough to prevent extrusion of a gasket or seal ring.

Reactor Auxiliaries

The type of reactor closure design and materials of construction are but two of the problems in construction of a high pressure pilot plant. Other high pressure units such as preheaters, separators, and pumps are required.

Some of the methods of solution of these problems may best be described by reference to a typical pilot plant for the study of liquid, liquid-gas, or gaseous reactions as shown on the opening pages. Plants of similar design have been operated at pressures to 25,000psi and to 1200°F.

Liquids are compressed to operating pressure by a positive displacement pump; the pumping rate determined by the use of either scales or liquid level indicators on the feed tanks. Incorporation of either a manual or automatic rate adjustment mechanism on the pump to allow rate changes without interruption of pumping is recommended, and the common pump auxiliaries such as relief valves and filters should be provided for pump protection. The pulsations which occur in liquid reaction systems due to the use of a positive deplacement pump may be eliminated by installation of a gas cushion on the discharge side of the pump. A liquid pump, as well as serving to pump liquid directly to the reaction system, can be used effectively to compress gases hydraulically, and this saves the added cost of a gas compressor.

Gaseous reactants are compressed and usually stored in high pressure accumulators of 1.0 to 1.5 cubic feet volume to allow intermittent operation of the compressor. Compressor auxiliaries such as dryers, filters and oil separators are required. Where corrosion is not a problem, accumulators for high pressure gas storage are constructed of heat-treated 400 series stainless steels or AISI 4340 steel. As accumulators are generally operated at room temperature, the inexpensive "O" ring closure is often suitable. A preheater, to bring the reactants to reaction temperature, can be easily constructed from a 30-40 foot length of heavy-walled high pressure tubing immersed in an electrically heated bath of liquid metal or molten heat transfer salt. Tubing up to 9/16″ OD x 3/16″ ID may be coiled without difficulty and with very little backlash after winding.

For catalytic studies in the research or development stage, sizing of pumps and problems of handling large quantities of materials generally lead to a choice of a reactor of ⅝″ to 1¼″ ID by approximately 30 inches long. The type of closure chosen is determined by the operating pressure and temperature used for design.

The reactor is often heated electrically by either attaching heaters directly to the body or by placing the unit inside an electric furnace. Separate temperature control over sections of the reactor is desirable to compensate for varying amounts of reaction throughout the length of the reactor. Temperature measurement throughout the length of the reactor is possible by insertion of a thermocouple well down through the reactor. For high speed heating, use of the reactor itself as a resistance heater has been found to be successful.

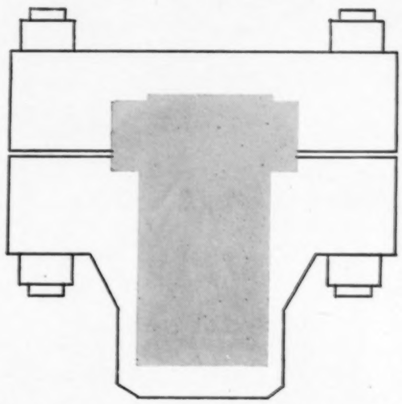
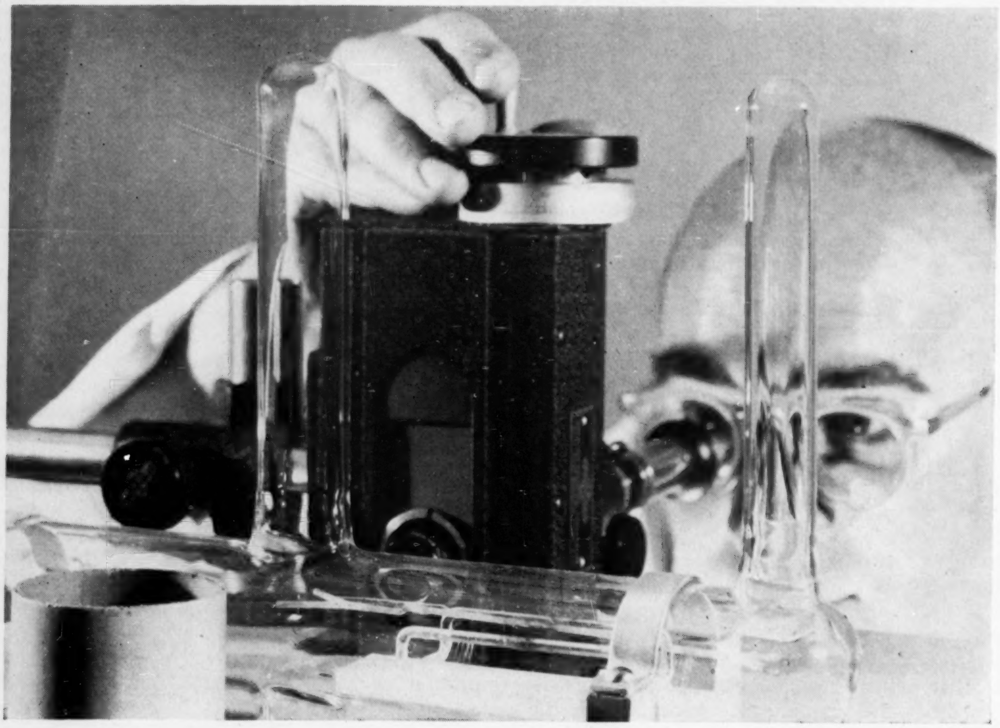


Fig. 6. Comparison of relative size of 2500psi autoclave today (color) and 25 years ago.

Depending on the process, it may be desired to separate liquid and gas at elevated pressure and/or temperature. In these cases the criteria for choice of closure construction as discussed above should be used. If the products can be separated at room temperature, a simple high pressure cooler-condenser can be constructed from a coil of high pressure tubing. Liquid level in the separator can best be controlled by a controller utilizing a capacitance-type probe. END

YARDSTICKS



How Many Atoms?

This quartz-bar microbalance is sensitive enough to weigh one layer of oxygen atoms. The beam is balanced on a tungsten wire 1/1000" in diameter. To insure maximum accuracy, the microbalance is sealed in an evacuated tube.

Developer: Westinghouse Research Laboratories, Pittsburgh, Pa.

For more data circle 46

Compact Scope

Passband on this general-purpose 5" scope stretches from d-c to 15Mc. The type 515 has 22 calibrated sweeps from 0.2 to 2 microsec/cm.

Developer: Tektronix, Inc., P.O. Box 831, Portland, Ore.

For more data circle 41

Low-Cost Accurate Shunt

Sensitive galvanometers can be utilized more flexibly by means of this relatively low-cost 9-step shunt. Carbon-metallic film resistances with individual tolerances of $\pm 1\%$ are used. It is finished with a chemically-resistant resin.

Developer: Fisher Scientific Co., 717 Forbes St., Pittsburgh, Pa.

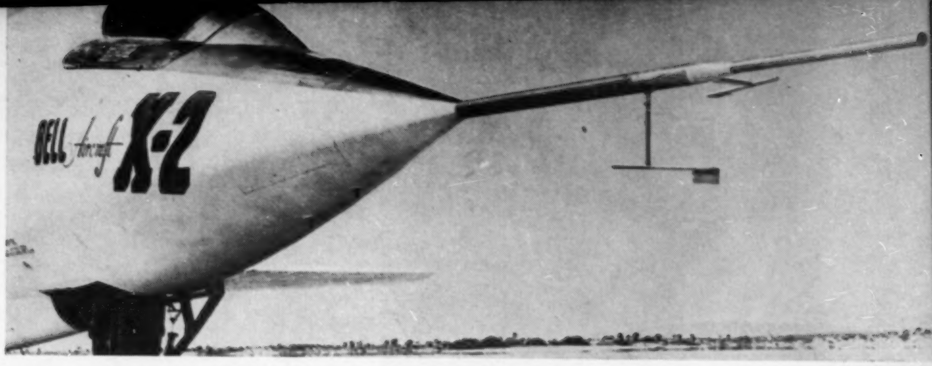
For more data circle 45 on p. 48

Monitors Radioactivity

Operating continuously for more than a week without attention, this mobile unit monitors airborne beta and gamma activity. Whenever permissible limits are exceeded, a light goes on and a bell rings. A permanent legal record of radiation levels goes on a continuous chart.

Developer: Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

For more data circle 43 on p. 48

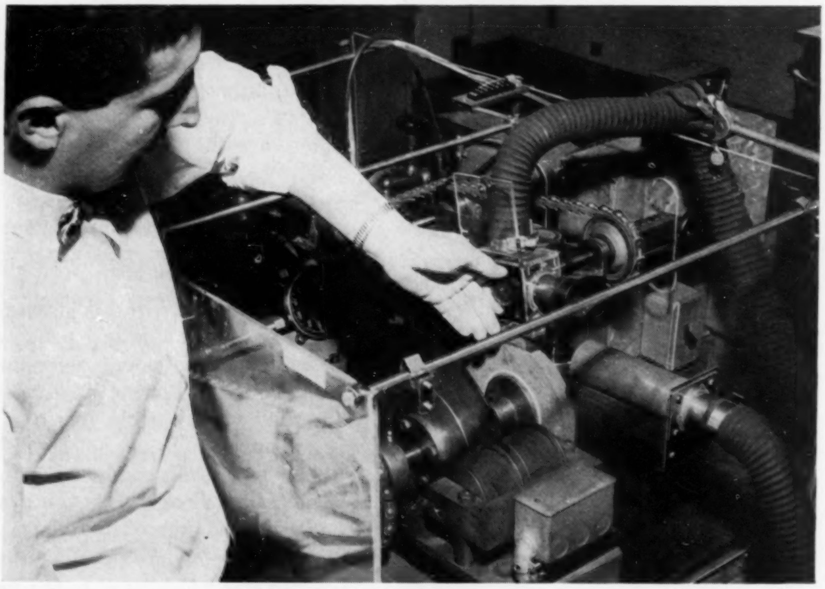


Probes the Unknown

Pilot-Static probe gracing the nose of the fastest rocket craft ever flown, the Bell X-2—designed to crack the thermal barrier and recently flown to a world's speed record of about 1,900 miles per hour. The heat resistant, stainless steel tube, with its two protruding vanes for registering angle of attack and yaw, was designed by National Advisory Committee for Aeronautics.

Manufacturer: Consolidated Avionics Corp., Westbury L.I., N.Y.

For more data circle 40 on p. 48



Tests Tiny Tires

Tiny inch-and-a-half replicas of butyl rubber tire give data for preliminary wear tests. Test device ran the tires against a revolving carborundum wheel, with electro-magnetic brake causing them to skid and slip to provide realistic wear results. Tire is shown being placed into position for test.

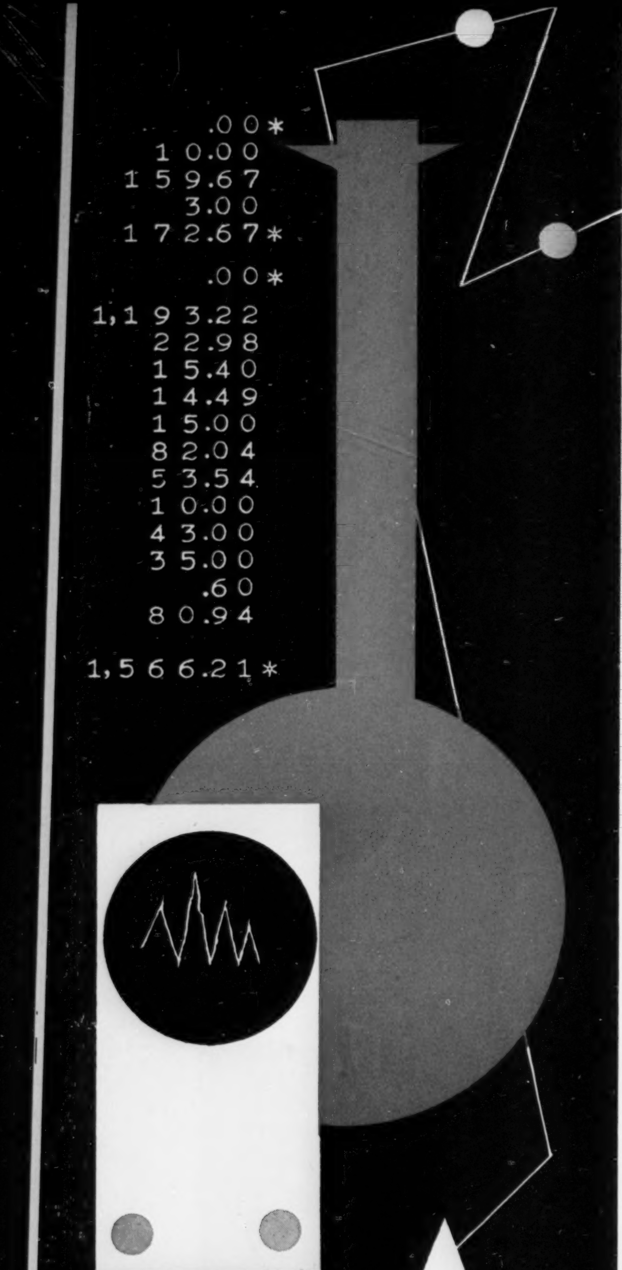
Developer: Esso Research and Engineering Company, 15 W. 51 Street, New York 19, N.Y.

Off-The-Shelf Reactor

Only 600 grams of U-235 of 20% enrichment make up the critical mass for this research reactor now in production. Radiation-stabilized polyethylene acts as the moderator. Costs less than $100,000, and it is portable. Along with the normal reactor safety interlocks, a thermal safety fuse built into the core enhances overall safety.

Developer: Aerojet General Nucleonics, San Ramon, Calif.

For more data circle 42 on p. 48



A revolution has taken place in control concepts within research and development divisions of our industrial community. Those who are leading the way have a distinct advantage over their competitors. Here are the characteristics of this new . . .

RESEARCH CONTROL

Turning the Research Dollar into Profit

RONELLO B. LEWIS

In no phase of business is the modern control concept more difficult to apply or more badly needed than in research. And yet, research does lend itself to specific control. Many corporations supporting operations by the best of reports, budgets, analyses and other control devices are only now belatedly moving such controls into areas of research. The trend points to the inevitable—research too, can and will be related to the profit dollar. Research will be controlled. The advancement and success of every professional researcher is inescapably linked to this truth. Here are specific suggestions that may help build a greater element of profit control into your research organization.

Economics of Research

Before control devices can be established there must first be an understanding of the basic stream of events which occurs between the spending of a research dollar and its return in the form of profit. First, of course, there are the breakdowns of spending within research itself. Some choose to divide research into two segments: applied and basic. There are those who agree that applied research is subject to profit control, while scuttling the entire idea of control when considering basic research. One hears the argument, "Yes, the control concept is good, but what about basic research?"

The answer to this is twofold. Less than 10% of all research conducted by manufacturing and processing corporations is basic research! This is hardly a large enough segment to provide a control problem.

Another answer to the control problem is that the breakdown into applied versus basic research is not the most significant division of expenditures, at least not from the point of view of expense control within the research division. A much more revealing classification, and one more amenable to control, is the grouping of all costs into either direct charges or overhead defined as follows:

- *Direct charges* are the out-of-pocket expenditures assigned to a project which itself is related to the improvement of present products or processes or to the creation of new products or processes. The direct charges include no proration for overhead or the general research establishment and its services. Such direct charges are incremental expenditures. They would be eliminated if the project were eliminated.
- *Overhead* includes that part of the research organization which would exist anyway regardless of the amount of project activity. It is the general research establishment, including research services and basic research.

At Olin Mathieson Chemical Corporation, where these classifications are used in reporting and controlling research expenditures, every dollar of research contains approximately 50¢ in out-of-pocket direct charges related to projects, and 50¢ of overhead. By controlling the specific projects, each of which carries a proportionate amount of proratable overhead, one obtains a measure of control over the whole. At the same time every effort is made to watch and budget the total overhead as if it were a project.

Interestingly enough, the Federal tax law gives a tax credit of 52%, but for sake of convenience here let's call it 50%, bringing the cost of a pre-tax research dollar to 50¢ after taxes. Thus when the corporation spends 50¢ out-of-pocket for direct charges on a project project, the relatable overhead brings the total cost to a dollar, which is again reduced to

Ronello B. Lewis, Vice President of Olin Mathieson Chemical Corporation performs the control functions in a business which has passed the one-half billion mark annual sales volume; the research establishment runs to some $25 million gross annually. Prior to joining Mathieson Chemical Corporation in 1953, Mr. Lewis was Controller of RCA. In 1951-52, he was a member of the Advisory Committee of Harvard University Graduate School of Business Administration's survey, "Spending for Industrial Research—1951-1952". Much of his article has been taken from material incorporated in his book "Accounting Reports for Management" to be published by Prentice-Hall early in 1957.

our starting figure of 50¢ net after taxes.

A more significant question in the economics of research is the relation of research to capital expenditures to support the improved or new products or processes, and in turn the relation of the proposed capital outlay to the stream of future operating profit to the corporation.

The correlation between research spending and profit has been obscured by time-lag, inflation and population growth, and by the difficulties in drawing a fine line between capital expenditures based on research and other capital expenditures of a replacement nature. The fuzziness in defining research itself is a further obstacle. Nonetheless, certain broad lines of cause and effect are observed. For example, illustration of the relationship can be given based on a review of the growth in the chemical industry over the past 30 years. This review permits us to be fairly specific.

After discounting for all of the above-named factors, it appears that every dollar of chemical research is matched on the average with three dollars of capital expenditure from which a 10-year sales volume of around $30 is generated. The stream of profits on a pre-tax basis relatable to this 10-year volume adds to $6, assuming a 20% return. On an after-tax basis, using an effective rate of 50% for Federal income taxes, the 10-year net profit adds to $3. On a cash basis, assuming a 10-year depreciation span, which for the most part is obtainable under present liberalized Federal income tax laws, the 10-year stream of cash thrown off is $5.40. This shows a pay-off of the research cost and capital outlay in six and one-half years. These figures could be discounted a third, and still conservatively show a full pay-off of research and capital outlay within the 10 years.

The foregoing relationships for the chemical field are the subject of some conjecture which will be given further treatment later in this article. Also, the relationships between research and long-range future profit return will vary from industry to industry. While this means that the final accuracy of a profit projection based on research cannot be assured, it nonetheless is clearly observable that important cause-and-effect relationships between the two factors do exist. Only the degree of relationship is open to question. It follows, therefore, that if some kind of rule-of-thumb can be expressed, knowing full well that a margin of error will inevitably exist, one will at least have moved a step closer to the proper control of research expenditures with the aim of relating the research dollar to its profit potential. Table 3 shows a picture of these relationships for the example just cited. These relationships establish some sort of par for the course to be used in appraising potential research projects.

Looking at Table 3, we can translate it into a researcher's thought processes. He might well say, "Let's see, if I spend this research dollar, I will have to allow 50¢ for overhead. That leaves 50¢ to spend out-of-pocket for direct charges. After allowing for taxes at 50%, the total project including overhead will fall back to a cost of 50¢ anyway.

"Assuming the project is successful, it will require $3 of operating investment to get in business for every dollar of research. The capital outlay of three dollars allows for property, plant and equipment of $2.40 which will be depreciated over 10 years, and working capital 60¢.

"Altogether the company will be out-of-pocket 50¢ for the after-tax cost of the research dollar, plus the $3 outlay for capital. That makes $3.50 which must be recovered.

"Now if we can get a turn-over of capital once a year, that will be $3 in annual sales. Assuming 20% return on sales, that will be 60¢ in pre-tax profit every year, or after taxes 30¢. Depreciation is worth 24¢ a year, so the cash throw-off is 54¢ annually. At this rate the $3.50 is recovered in 6½ years!"

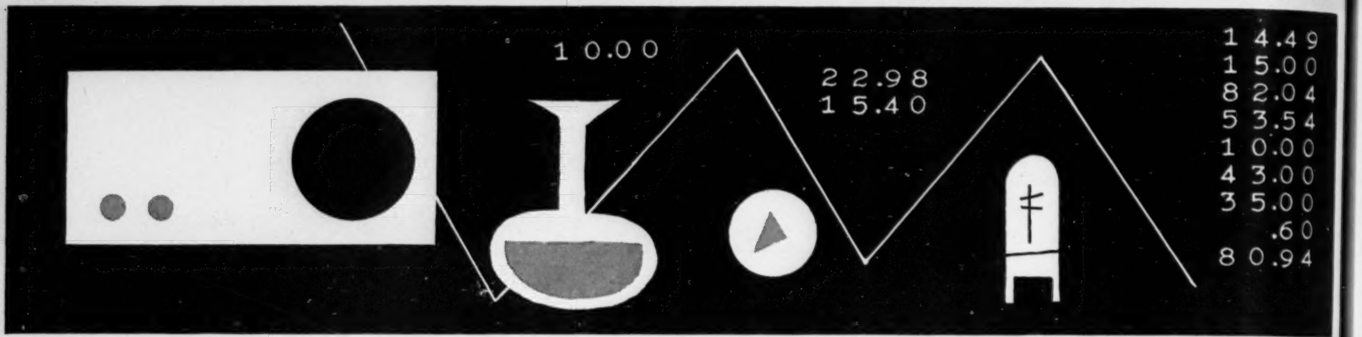
All of these amounts have been related to the research dollar. The same numbers could be multiplied by 100, 1000 or 1,000,000 and the relationships would be the same.

The important thing is not so much that these particular standards be accepted. Each company should establish its own. But it is important that some minimum standards exist. Then potential projects which fall below this minimum can be tabled, while those that come above can be placed on the agenda for management review and action.

The next section of this article on "project control" is based on the assumption that such minimum standards have been established as a basis for appraisal of specific projects for new or improved products or processes. One might raise or lower the sights from those illustrated, or one might use different terminology, but the sum and substance of control in any event would be reduced to a format containing more or less the same sequence of related elements as that which is illustrated here.

Before going further into the recommended steps in research control, we might pause a moment at this point to view further the analysis of significant relationships for chemical industry. A similar analysis for any industry could be made from an observation of the past correlation between research spending and profit. Those shown in Table 1 range from a Low to High with the latter coinciding with the relationships mentioned in the preceeding paragraphs and used on Table 3.

The relationships shown in the above table were based on a review of the trends and results reported by the chemical industry for the past three decades. Allowances were made for time-lag, inflation and population growth. An effort was also made to eliminate capital expenditures of a replacement nature. The result of the study is the range shown. When it is realized that this range reflects the non-productive research, the failures as well as the successes, it is easier to interpret the relationships. (*Continued on p. 40*)



Looking back, one could conservatively say that every dollar of research had generated two to three dollars of capital expenditure, 20 to 30 dollars of sales over 10 years, and three to six dollars of pre-tax profit over the same period. The ratio of profit to the research dollar was between a low of 3 to 1 and a high of 6 to 1, and this was true on both a pre-tax basis as well as after taxes.

Table 1.

	Low	High
	In Millions	
Chemical industry research 1956	600	600
Cost on after-tax basis	300	300
Future capital expenditures	1200	1800
Per research dollar	2.00	3.00
New sales volume over 10 years	12,000	18,000
Per research dollar	20.00	30.00
Pre-tax profit over 10 years	1800	3600
Per research dollar	3.00	6.00
Net Profit over 10 years	900	1800
Per research dollar	3.00	6.00
Ratio of profit to research dollar	**3 to 1**	**6 to 1**

Looking forward, one is naturally looking for successes. Hence, the high range of the scale becomes the goal, the rule-of-thumb, the guide, or the point of reference in the appraisal of proposed research expenditures.

If we then take this view, the $600 million which is being spent for research within the chemical industry in 1956 may well generate a potential $1.8 billion in future capital expenditures, $18 billion in sales spread over a 10-year span, and $3.6 billion in pre-tax profit over a similar period. These enormous figures apply only to the chemical industry in which the estimated 1956 research expenditures of $600 million represent about one-fifth of a projected $3 billion in industrial research spending

Table 2. Research expenditures.

DIRECT CHARGES	Spent This Month	Spent To Date	% 1956 Budget Spent	1956 Budget
Salaries	25,000	200,000	67	300,000
Payroll, taxes, etc.	1,000	10,000	67	15,000
Materials and Supplies	25,000	200,000	95	210,000
Travel and telephone	2,000	10,000	67	15,000
Outside services	3,000	15,000	50	30,000
Occupancy	1,000	10,000	67	15,000
Charges from other depts.	1,000	6,000	100	6,000
Miscellaneous	1,000	10,000	111	9,000
DIRECT CHARGES	59,000	461,000	77	600,000
Billings to Govt. & Others	3,000	20,000	40	50,000
NET RESEARCH TO DIRECT CHARGES	56,000	441,000	80	550,000
NET RESEARCH OVERHEAD	26,000	207,000	75	275,000
NET RESEARCH	82,000	648,000	78	825,000
Number of employees	96			

this year for all processing and manufacturing firms. Speculate if you will on the strengthening and sustaining impact that these expenditures are bringing to the economy of the nation over the long pull, and on the increasing significance of research in industry and the importance of aiming the research dollar within every industrial enterprise through proper controls toward its long-term profit potential.

With this correlation between research and profit as a background we move now to the research project budget worksheet itself and to the more specific forms and reports recommended for the measurement and control of research expenditures.

Research Project Budget

Table 4 illustrates a typical project budget worksheet for use in an industrial company where an effort is made to relate each out-of-pocket research dollar to its profit potential. We might as well assume that the research arm of the business consists of a number of divisional segments each headed by a research manager; and that within each such segment there is an overhead group as well as a larger group of directly relatable researchers working on specific projects, each of which is headed by a research project engineer. Before coming into being, it might be assumed also that the research project has been blueprinted into a detailed program expressed in story form in a document prepared by the project engineer. The recommended figures to accompany such a project or proposal are shown in Table 4.

Naturally the project engineer will draw on the controller's department for figure assistance in putting together the financial part of the project. Or at least, if figure help is not solicited in the first instance, it would be expected that the project form would be channelled through the controller's department for checking and approval before being sent to higher levels for final action. Eventually, the project would be moved along for review and approval to the division research manager, the general research manager and to the research and development committee or executive operating committee, or to whatever top management group is empowered to act finally on the proposal.

In many companies a controller for research acts as an aid to and as a check upon the research division in the controlling and reporting function. In such cases, the research controller and his assistants work with the scientific or professional-technical personnel within the research establishment in the preparation of project budget worksheets. In these instances the research controller sets up as a part of the research division of the corporation, reporting to and serving the General Research Manager administratively, but answering functionally to the Controller of the Corporation.

A project worksheet can be prepared initially at the inception of the project, but the chances are it will be revised at least once and probably several times during its life. Naturally, it should be revised whenever conditions change, so that it constantly reflects the latest thinking. Under one suggested method, the project worksheet is prepared initially at its inception, and is

revised each January First as a part of the annual research budget. In this way the project itself, which may cover a research span of several years, is properly related at the beginning of each new fiscal year to the annual research budget covering the area of spending for the specific 12 months at hand.

This approach forces a fresh look at each research project at least annually, and brings about a reconciliation periodically between the list of pending research projects and the corporation's spending allowance for research in a given year. Almost invariably this reconciliation will reveal a list of projects somewhat in excess of the corporation's allowable funds for research in the budget year. This causes some pruning of projects. Others are deferred or eliminated, and a "survival-of-the-fittest" approach is then adopted to produce a series of project budgets for the current year adding to the corporation's research budget total. Naturally, the yardstick is profit potential, or at least an attempt is made to make it so. In theory, and in large part also in actual practice, the corporation ends up under this approach by putting its effort into those projects which do carry the promise of an interesting profit return, again measured by the common denominator—percent return on invested capital.

The accompanying project budget worksheet, Table 4, is in three parts. The top section shows the estimated research spending for the life of the project. Overhead is added as a percentage of direct labor, and the total cost of the project is shown on both a pre-tax and after-tax basis. The first column shows actual spending to date since the inception of the project, the second column is the proposed spending for the budget year at hand, the third column shows proposed project spending carried over to future years and the fourth column is the total cost of the project. The middle section shows the expected outlay for property, plant and equipment and working capital to put the project into operation, and the bottom section shows the estimated effect on sales and profit.

Looking at the annual operations shown on the bottom of the project worksheet, we find three columns showing, respectively, annual sales and profits before reflecting the project, annual sales and profits after reflecting the project, and the effect or difference between the first two. It is this difference that is related to the outlay on the project to determine its percentage of return and payout period. In analyzing the project of Table 2 the following salient facts stand out:

- actual spending on the project to date, through 1955, is $90,000;
- proposed spending in budget year 1956 is $120,000;
- estimated spending to complete the project in 1957 is $40,000;
- the total pre-tax cost over the three years, 1955 to 1957, is estimated at $250,000, including direct charges $150,000 and overhead $100,000; direct charges are high in this instance due to $85,000 outlay for materials;
- the after-tax cost of the project is $125,000; this allows 50% for Federal income taxes;
- the plant, property and equipment investment to put the project into operation is estimated at $600,000; working capital is estimated at $150,000;
- the outlay to be recovered, i.e., after-tax cost of research plus plant property and equipment and working capital is $875,000;
- before reflecting the project, annual operations show sales of $1,250,000 and net profit of $75,000;
- after reflecting the project, annual operations are estimated to show $2 million sales and $150,000 in net profit;
- the effect of the project is $75,000 in additional annual net profit, or a 10% return on capital to be invested;
- adding back annual depreciation, the annual cash profit is $135,000;

Table 3. Relating the research dollar to profit.

THE RESEARCH DOLLAR BEFORE TAXES	1.00
THE RESEARCH DOLLAR AFTER TAXES	.50
Related property, plant and equipment	2.40
Related working capital	.60
TOTAL OPERATING INVESTMENT	3.00
TOTAL OUTLAY FOR RESEARCH AND OPERATIONS	3.50
SALES VOLUME PER YEAR	3.00
Annual turnover of operating investment	1.00
PRE-TAX PROFIT PER YEAR	.60
% to sales	20%
% return on operating investment	20%
NET PROFIT PER YEAR	.30
% to sales	10%
% return on operating investment	10%
DEPRECIATION PER YEAR—10 YEAR BASIS	.24
CASH PROFIT PER YEAR	.54
Payout of total outlay for research and operations	6½ years

- dividing $875,000 outlay by $135,000 cash profit shows a payout period of six and one-half years.

This is only one of many illustrations that might be given of a project worksheet. Some projects are completed within a single year. Others are spread over several years. Some involve heavy capital expenditures, while others require relatively little outlay for property, plant and equipment and related working capital. Some represent improvements in existing operations, and their effect is measured by comparing operations before and after the proposed change or project installation. Others are new operations involving no change in those already existing. In any and all of these situations the accompanying project sheet provides the framework for reporting the essential figures.

At budget time on, let us say, January 1 of each year, each project is written up in the form illustrated on Table 4, and the amounts in the current year budget column, when added through, support the total research budget. Sub-totals for each research center or sub-division are obtained separately for direct charges and overhead, each of which is broken down into its essential natural elements—salaries, materials, travel, and so on, and the whole is again supported by the project totals. Thus, responsibility is assigned by research center or sub-division, the overhead element is established as a group within the total for the center, and the direct charges are controlled by project, all within the framework of the management approved research budget. There then remains the problem of carrying out the budget program during the year.

It should be noted under this system that all project costs are expressed in two ways. One, direct charges only. Two, total project costs including direct charges and overhead combined. Number two is nothing more than an interesting statistic in which overhead is prorated to the projects. No control is achieved from this proration and, indeed, there are many in the controllership fraternity who would do away with such prorates altogether. Those who follow this course contend that research is controlled:

- first, by delegating responsibility and authority to divisional centers of operation which become centers of control;
- second, by splitting all expenses within each research center between the relatively fixed elements which are called overhead and the relatively variable elements which are called direct project costs;
- third, by controlling the overhead within each center as if it were a project in itself; this means no proration of such overhead to individual projects;

• fourth, by controlling the variable direct costs on a project basis.

Reporting Research Expenditures

A typical monthly research report for a research center or sub-division is shown in Table 2. Similar reports would be prepared for each of the other centers, and a recap for the total corporation. Spending to date of $648,000 is 78% of the full year's budget of $825,000. With four months still remaining, this research division is obviously headed for trouble. If it were "on course" only 66% would be spent in the first eight months, leaving 33% for the remaining four.

Another suggested report breaks down the direct charges by project. Overhead would not be assessed to the individual projects, but instead added as a single element at the bottom of the page. This spread of research expenditures by projects gives two vital comparisons. One, it compares the year to date project spending against the original budget for the year. Two, it compares the total project spending to date not only for this year but for prior years as well with the total spending for the project as estimated for all years combined. Thus, on one project for example, the year to date spending of $40,000 is 67% of the 1956 budget of $60,000. But, going back to the beginning of the project, it is found that cumulative spending of $110,000 is 73% of the total project estimate of $150,000.

The examples in this article are a cross-section of the many pages of data that would usually be issued as a part of the research budget or monthly reporting system, but they are sufficient to illustrate the significant elements in one suggested approach to the problem of research control with the accent on profit.

END

Table 4. Project budget worksheet.

OUTLAY	1955 and Prior	1956 Budget	1957 and Future	TOTAL
Date to start and finish	1-1-515	xxx	12-31-58	3 years
NET RESEARCH DIRECT CHARGES Net research overhead	70,000 20,000	60,000 60,000	20,000 20,000	150,000 100,000
NET RESEARCH—PRE-TAX BASIS	90,000	120,000	40,000	250,000
NET RESEARCH—AFTER TAX BASIS	45,000	60,000	20,000	125,000

	Before	After	Effect
Property, plant & equipment Working Capital	1,000,000 250,000	1,600,000 400,000	600,000 150,000
TOTAL OPERATING INVESTMENT	1,250,000	2,000,000	750,000
TOTAL OUTLAY			875,000

	Annual Operations		
	Before	After	Effect
Sales Annual turnover of operating investment	1,250,000 1.0	2,000,000 1.0	750,000 1.0
Depreciation Other costs	100,000 1,000,000	160,000 1,540,000	60,000 540,000
PRE-TAX PROFIT % to sales	150,000 12.0	300,000 15.0	150,000 20.0
Federal Taxes	75,000	150,000	75,000
NET PROFIT % return	75,000 6.0	150,000 7.5	75,000 10.0
CASH PROFIT Payout	175,000 xxx	310,000 xxx	135,000 6½ years

s'Gravesande's Stoomwagen

s'Gravesande's Steam Reaction Car

In 1721 Jacob Willem s'Gravesande of Delft, stimulated by the recently enunciated Third Law of Motion, astounded the Royal Society by constructing a practical steam reaction car. The vehicle actually moved several times its own length, a distance of about two meters.

In 1956 the goal is no longer meters, but hundreds, and even thousands, of miles. Aerojet-General Corporation, leader in American rocket propulsion for more than a decade, is proud to participate in man's first assault on the frontiers of outer space—Project Vanguard.

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Letters

Realistic View

Baltimore, Maryland

In the introductory section of the interesting article "The Formulation of Problems in Research" there are some comments on the important subject of selecting research projects. As I understand it, the key points are (1) We do not do enough fundamental research, and (2) This is at least partially the result of administrators who are not well qualified to select the proper projects.

I heartily agree with the first contention but I believe that the cause is quite different. We operate in a society of competitive companies each concerned with making a profit. Fundamental research, by definition, has no definite commercial objective. It may benefit the world more than an equivalent amount of applied research, but it is not likely that it will have this benefit for the company that pays for it. In our present society it is unrealistic, even "unnatural", to expect men to spend money on a project that may not benefit the investors, regardless of how much it contributes to the general welfare.

Yes, we must campaign for more fundamental research but we must not dissipate effort by fighting on the wrong battlefield. Such research will never be sponsored in sufficient amounts by individual industrial companies in our society. Rather our effort must be devoted to obtaining support from those who would obtain the benefits—the associations of companies, or even all the people of the United States, through their taxes . . .

CARL PACIFICO
Vice President
AMERICAN ALCOLAC CORP.

Reliability Problem

Falls Church, Va.

Your magazine has been extremely interesting reading and fills, I think, an important need.

The inadequate recognition given to the more experienced engineers, mentioned in your April issue, may be a key to a problem which at first glance seems far afield: reliability in military electronic equipment. This reliability problem has been, for several years, publicized as serious to the point of crisis. Now, to develop and design a device that will merely work is a job for an ordinary development engineer. But a feeling for the complex subtle relationships which dictate accuracy potentials, margins of stability and safe-failure properties, is not found in novice or run-of-the-mill technical talent. Nor is a simultaneous grasp of the overall picture plus the details. All this is quite necessary in developing complex stuff for reliability. The alternative is the succession of breakdowns of the product in the field, patched up by a series of substitutions and modifications.

To get the technical job done right in the first place requires, I believe, engineers of good training, superior talent, strong imagination, and long experience. These are the people who leave straight engineering for management or sales.

LAWRENCE FLEMING

More Case Studies

Louisville, Ky.

Just a word to say that I am very pleased to be on your mailing list to receive RESEARCH & ENGINEERING. I am always skeptical when a new publication is launched in an already crowded field. However, you have had many directly helpful articles. I have been particularly interested in those dealing with research planning, management, evaluation, etc.

Your current issue has touched on an important subject in your "Rating of R & D Supervisors". More case studies are needed in this area. Recently I have been studying the A.M.A. book "Effective Communication on the Job". This contains many stimulating suggestions.

As more data accumulate, I would be interested in case studies and actual results achieved with the type of "forced choice" evaluation such as is described by Mathew Radom in Perry's "Chemical Business Handbook".

H. W. PUTNAM
Technical Manager, New Products Development Section
PILLSBURY MILLS, INC.

The Forgotten Man

Clarkwood, Texas

The article by Herman Skolnick "Planning an R & D Information Center" in your July issue was especially interesting. A rather notable omission was apparent in the discussion so far as I was concerned in that no mention was made of the importance of the people that go into the R & D information center. No matter how cleverly organized or skillfully designed, a research and development information center that does not have highly intelligent, well-trained *people* will fall flat. Some mention is made of the extent of training necessary for the librarian, whether he is a B.S. or a Ph.D., must first have sufficient scientific background to be a qualified researcher himself and be as well thoroughly familiar with technical libraries both from an organizational and a functional standpoint. Needless to say, such a person is indeed a rare bird. More important, moreover, than any degree of formal training or background is the absolute necessity of a high order of intelligence and a vast, retentive memory . . .

FRANK S. WAGNER
Technical Librarian
CELANESE CORP. OF AMERICA

Not Generic

Chicago, Ill.

Our client, Motorola, Inc., has called to our attention an improper use of one of its important trademarks in your June, 1956 issue and has asked me to write to you and solicit your help in avoiding such use in the future. On page 28 of the above issue, at the top of the page there is a photograph and a description which reads as follows: "Engineers at the Signal Corps' Fort Monmouth Engineering Lab developed the technique to stretch our supplies of strategic quartz, now mainly imported from Brazil. About 50 wafers are used in a handy-talkie, for example."

HANDY-TALKIE is the registered trademark of Motorola, Inc. . . . You may be familiar with the fact that a trademark owner will lose its rights if it permits the use of its trademark either as a generic word for the product such as it is used in your magazine, or if the owner permits the use of the trademark in connection with equipment not sold or manufactured by the trademark owner. Although I cannot say for sure as to the equipment to which the description refers, I can definitely say that the use in the magazine is as a noun, or a generic use, and this is the basis of the present request . . .

FOORMAN L. MUELLER
MUELLER AND AICHELE
COUNSELORS AT LAW

Inverted Illustration

Cleveland, Ohio

In your June issue, you were kind enough to illustrate our LPD Oil Bath Filter on Page 29. However, you inadvertently ran the illustration upside down. While there may be many readers who will understand this occurrence, it does make a most peculiar filter illustration.

W. B. WATTERSON
Vice President of Sales
AIR-MAZE CORPORATION

Editor's note: We agree—it did make a peculiar illustration. Wonder how many of our readers spotted it?

French Jet Engine Misplaced

Stratford, Conn.

Your attention is called to an article head-lined "French Electronic Skills Imported" in the April issue of your magazine and to the statement therein that "A small French jet turbine has been licensed by Lycoming . . ."

The statement is in error, and the error has particular significance for the company in the light of our development of a small gas turbine engine, the XT53. You will understand that Lycoming is particularly proud of this engine, the first of its kind to be designed and developed in America . . .

ROBERT W. STOCK
News Bureau
AVCO MANUFACTURING CORP.

Editor's note: Our error. The French jet turbine was licensed by Continental Engine.

R/E views the books

Microwave Spectroscopy

BY C. H. TOWNES AND A. A. SCHAWLOW

Reviewed by John D. Blades, Burroughs Corporation.

Through the rapid development and perfection of the components and techniques of microwave systems in the past ten years, the oldest and stablest field of modern physics, spectroscopy, has once again extended its frontiers of basic research. The utilization of new high frequency radio systems by the spectroscopists has provided the opportunity to measure and interpret the energy levels of molecular gases, to reinvestigate many phases of atomic spectra with a greater degree of resolution, and to extend the knowledge thereby gained to a reinterpretation of nuclear, electronic, and molecular phenomena. The authors of the present manuscript have pioneered and made many original contributions to this new field of science, which has finally reached a stage in its development where a book of this type could be useful and of lasting value.

The scope of the volume is broad and satisfies its purpose of being a review and reference source. Missing details of rigor can be obtained by pursuance of the excellent appended bibliography. The main body of the text begins with a fundamental, quantum mechanical treatment of molecular spectral physics. This is followed by interpretations of quadrapole hyperfine angular momentum, magnetic hyperfine structure, hyperfine coupling constants, the Stark and Zeeman effects, and the ammonia spectrum. Special attention is given to the physical factors effecting the shapes and widths of spectral lines (natural line breadth, Doppler effect, pressure and saturation broadening, and collision effects). With a basic theoretical foundation the reader next is introduced to the microwave systems and techniques that observe the spectra of molecular gases. In conclusion the authors examine the possible uses and limitations of microwave spectroscopy for the purpose of gas analysis, thus emphasizing to the comprehending reader basic information needed for such applications.

Besides the already noted bibliography, the appendices include extensive, convenient and useful tables pertaining to intensities, energy levels and coupling and molecular constants that are essential for a complete study of gaseous microwave spectroscopy. The inclusion of this data particularly enhances the richness of the author's efforts.

An elementary knowledge of quantum mechanics and a good comprehension of atomic physics is a prerequisite for this volume. On the other hand, many of the higher mathematical interpretations existing in microwave spectroscopy (group theory) have been avoided. *Microwave Spectroscopy* serves well as a reference and orientation source for the graduate student and the novice research scientist, and will be a substantial aid to those already working in the Spectroscopy field.

McGraw-Hill Book Company, Inc., 698 pages, $12.50.

The Analytical Theory of Heat

BY JOSEPH FOURIER, TRANSLATED BY ALEXANDER FREEMAN

Reviewed by Israel Katz, Consulting Engineer, General Electric Company.

Even after eighty years of sustained scientific probing and thought in the realms of classical and applied thermodynamics, Joseph Fourier's monumental Analytical Theory of Heat remains a formidable beacon illuminating the treacherous shoals of fact and fancy concerning heat and related phenomena.

The by-products of this great treatise affecting modern science and technology in fields near and far from thermodynamics, are incalculable.

Alexander Freeman aptly stimulates our interest by pointing out that two groups of readers will find this book indispensable: those concerned with the theory of heat per se, and those interested in the mathematical tools which Fourier developed. The work discusses radiant heat; cause and reflection of rays of heat; mode of communication between internal molecules; uniform and linear movement of heat; heating of closed spaces; movement of heat in a ring, solid sphere, solid prism, solid cube; the use of trigonometric series in the theory of heat; propagation of heat in an infinite rectangular solid, highest temperatures in an infinite solid, etc.

Those persons who are concerned with matters of heat, but do not have a copy of Fourier's treatise at hand cannot continuously appreciate the timeless qualities of the work and the indispensable help it affords in explaining to themselves, with breadth and insight, the many perplexing aspects of modern scientific knowledge. Moreover, they cannot benefit from Mr. Freeman's brilliant grasp of thermodynamics and his appreciation for detail without which this outstanding translation would have been impossible.

Dover Publications, Inc., 466 pages, $1.95

Research Reports

Reports in this section may be obtained directly from the Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C., unless another source is stated.

Protective Coatings

A two-part report describing Air Force-sponsored studies of heat resistant corrosion protective coatings for low alloy steels for use in aircraft. Part I presents a method for testing these coatings in two artificially created environments. These procedures are described, and results of tests on 16 different coatings are given.

Part II describes diffusion coatings produced by chromizing and siliconizing which showed considerable promise as protective coatings for low to medium carbon, plain carbon or low-alloy steels at temperatures up to 1200°F.

EVALUATION OF SURFACE TREATMENTS FOR LOW-ALLOY STEELS, *Part I, PB 121087, 29 pages, $.75; Part II, PB 121088, 21 pages, $.75.*

High Impact Tests

Two reports. The first deals with a pneumatically driven impact tester which was designed to evaluate the dynamic performance characteristics of cushioning materials. An analog computer was used in a new application to record and analyze impact. Describes details of construction and operation of the machine.

DESIGN AND DEVELOPMENT OF A HEAVY WEIGHT HIGH IMPACT SHOCK MACHINE, *PB 121198, 39 pages, $1.00.*

The second report gives the results of tests of paper-board honeycomb materials on the device described above. Energy absorption characteristics were determined for certain commercial paper-board honeycomb materials impacted under a heavy weight high impact shock machine. A correlation between energy absorption and density is shown.

PERFORMANCE CHARACTERISTICS OF PAPER HONEYCOMB CUSHIONING MATERIALS IMPACTED UNDER A HEAVY WEIGHT HIGH IMPACT SHOCK MACHINE, *PB 121183, 62 pages, $1.75.*

Permeability of Polyethylene

Two reports. An Air Force study of the permeability of polyethylene establishes equations for permeability of the material, along with master plots for interpolating homologous materials and extrapolating for temperature changes. A bibliography is included for permeability, solubility and diffusion in polymer systems.

THEORETICAL INVESTIGATION OF THE MECHANISMS OF TRANSFER OF MATERIALS THROUGH POLYETHYLENE, *PB 121194, 93pp., $.75.*

The second report discusses problems concerning circular plastic plates under rotationally symmetric conditions of loading and support. This serves as an introduction to a number of recent, detailed papers on the subject, some of which are not readily accessible.

THE THEORY OF PLASTIC PLATES, *PB 111943, 24 pages, $.75.*

Metals Research

Two reports. The first is on extended investigations into delayed failure and hydrogen embrittlement in high strength steel under commercial electroplating conditions. The temperature dependence of the delayed failure time indicated that crack propagation was controlled primarily by the inward diffusion of hydrogen.

HYDROGEN EMBRITTLEMENT AND STATIC FATIGUE IN HIGH STRENGTH STEEL, *PB 121064, 41pp., $1.25.*

The second report deals with the results of the application of force tendency, a concept of driving force per unit crack front, to fracturing in metals. Measured values of the crack extension force at the onset of fast fracturing, and practical use of critical values of crack extension force are given.

ONSET OF FAST CRACK PROPAGATION IN HIGH STRENGTH STEEL AND ALUMINUM ALLOYS, *PB 121224, 16 pages, $.50.*

Air-Conditioning Aloft

A detailed guide for aircraft designers in calculating air-conditioning loads for aircraft compartments. Methods of analysis are simplified for routine calculations, and graphs, procedures outlines and sample problems illustrate much of the information needed for computation of heating and cooling loads. Important design factors are discussed.

ENGINEERING STUDY OF AIR-CONDITIONING LOAD REQUIREMENTS FOR AIRCRAFT COMPARTMENTS, *PB 121139, 177pp., $4.50.*

Low-Temperature Properties

A 400 page compilation of pre-1952 data on low-temperature properties of metals. Valuable as a background guide for designers and fabricators of low-temperature equipment, it contains papers presented at a Conference of Materials and Design for Low-Temperature Service. An extensive bibliography is included.

CONFERENCE ON MATERIALS AND DESIGN FOR LOW TEMPERATURE SERVICE, *PB 121009, $10.00.*

Here's a brief review of last month's product and service advertising in RESEARCH & ENGINEERING as a service to our readers.

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with lab-equipment precision have given superior performance in many atomic energy projects. Standard or specially designed reactors available, featuring confined gasket closures.
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National Polymer Products, Inc.
Reading, Pennsylvania

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provide a combination of properties that fulfill requirements in many industrial products and processes, such as lubricating grease, ceramics, air conditioning, glass, and many others.
Foote Mineral Company,
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permits investigation and development of ultrasonic effects over the entire spectrum. Applications include depolymerizing, impregnating, degassing, electroplating, fragmenting, dispersing and accelerating chemical reactions.
The General Ultrasonics Company,
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Carl Zeiss, Inc., 260 Madison Avenue,
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in four homologous forms can be used as emulsion stabilizers, wetting agents, penetrants, anti-oxidants, cleaners, anti-foaming agents, and in many other operations.
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